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PLANNING AND CONTROLLING
THE ACQUISITION COSTS OF
AIR FORCE INFORMATION SYSTEMS

THESIS

Thomas J. Falkowski
Captain, USAF

AFIT/GIR/LSY/88D-5

DEPARTMENT OF THE AIR FORCE

AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

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PLANNING AND CONTROLLING

THE ACQUISITION COSTS OF

AIR FORCE INFORMATION SYSTEMS

THESIS

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Information Resource Management

Thomas J. Falkowski, B.S.

Captain, USAF

December 1988

Approved for public release; distribution unlimited

Preface

The purpose of this study was to identify what
indicators can be used to more efficiently control the
acquisition costs of Air Force information systems. Air
Force expenditures on information systems to support their
mission are substantial; cash outlays are in the billions of
dollars. Because of this, any tools that can be used to
improve the planning and control of the acquisition process
can be extremely valuable.

Statistical analysis was performed on acquisition data
collected from information systems acquired under AFLC's
Logistics Management Systems Modernization Program.
Although the limited size of the sample data make the
results inconclusive, the methodology presented here
provides a means to identify potential indicators.

Throughout my research, data collection, statistical
analysis and compilation of this thesis I have depended on
the support of many people. My thanks go to my faculty
advisor, Lt Col Jeff Phillips, for his encouragement,
support and expertise. I would also like to thank my
classmate, Capt Al Dunn, whose on going discussions of
statistical techniques proved extremely useful in the choice
of statistical analysis techniques. My greatest thanks,
however, go to my family. To my daughter ███████ and to my
son ██████ who both always seemed to understand when Daddy
was "too busy." And finally, my deepest and heartfelt

thanks to my wife ███████ Her understanding, patience, and love, provided the impetus for this, and all of my endeavors.

<div align="right">Thomas J. Falkowski</div>

Table of Contents

List of Figures

List of Tables

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Abstract

The purpose of this study was to identify indicators that can be used to more efficiently control the acquisition costs of Air Force information systems. Statistical analysis was performed on cost data collected Cost/Schedule Status Reports from information systems acquired under Air Force Logistics Command's Logistics Management Systems Modernization Program. Using regression analysis, an initial model was developed that showed the importance of various cost areas on contract performance. The model was then transformed, and reduced, to include only those variables that added significantly to the prediction of contract performance.

Based on the sample analyzed the following cost areas were identified as key indicators of contract performance: Software, Test and Evaluation, Training, and Maintenance. Although the limited size of the sample data make the results inconclusive, the methodology presented here provides a means to identify potential indicators. The goal of this research was not to provide a definitive model that would help program managers to predict contractor performance. Instead, the goal was to establish procedures, or motivation, for program managers to identify key control

variables that can help them to manage their programs more
effectively in a time of austere budgets and restricted
manpower availability.

PLANNING AND CONTROLLING THE ACQUISITION COSTS OF AIR FORCE INFORMATION SYSTEMS

I.   Introduction

Background

An organization's success is dependent, in part, on its ability to plan and control its operations. All major organizational components must have a plan of action, and corresponding control mechanisms, in order for the organization to perform effectively. Fayol, who introduced the idea that a manager plans, organizes, coordinates, and controls, states that a plan of action is one of the most important matters that every business must deal with (8:89). Of equal importance is control. "Control consists of procedures to determine deviations from plans and indicate corrective actions" (3:315).

These planning and control issues are extremely important in dealing with information systems. Management has only recently recognized that information is a resource that must be managed like any other resource within their control (12:3). This information resource is being increasingly managed by automated information systems. In many cases the planning and control must deal not only with

existing systems, but also with the acquisition of new systems that represent a large cost to the organization. This leads to the issue of how the planning and control of the acquisition of information systems can be improved.

Problem Statement

Planning for the acquisition of information systems is, at best, a complicated process. Many issues must be considered within the organization. In addition to internal considerations, there are many external factors that complicate the process; technology is expanding at a rapid rate. The scope of the acquisition process is too broad to consider all of the issues that impact it. This research will center around budget concerns in an attempt to develop a quantitative model to assist in the controlling of acquisition costs by predicting contractor effectiveness.

Research Objectives

The objectives of this research are (1) to identify what indicators can be used to more efficiently control these costs and (2) to build a prediction model around these indicators.

Investigative Questions

In order to meet the research objectives, I will answer the following investigative questions:

1. Which, if any, individual cost variances signal total system cost overruns?

2. What is the observed relationship between the individual costs and contract performance.

Justification

Air Force expenditures on information systems to support their mission are substantial. One example of this is the Air Force Logistics Command's (AFLC) $1.7-billion Logistics Management (LMS) Systems Modernization Program (17:1). The purpose of the LMS Modernization Program is to update the information systems supporting AFLC's worldwide mission.

Scope

The purpose of this study is to examine the observed cost breakdown of information systems acquired under the Logistics Management Systems Modernization Program. Individual cost areas will be looked at over time in relation to overall program costs. The observed costs will be compared with budgeted costs to determine the corresponding cost variances. The variances will then be examined to determine if specific variances can be used as predictors of overall system cost overruns.

Limitations

Because the population of the study is confined to information systems purchased in support of AFLC the ability of the findings to be generalized to information systems for other major commands may be limited.

II. Literature Review

The concepts of planning and controlling are found throughout the management literature of the past 60 years. It is just recently, however, that the integration of planning and controlling has been addressed. Planning has been described as "a predetermined course of action [that] represents goals and the activities necessary to achieve those goals" (3:300). Controlling, on the other hand, represents "the activity which measures deviations from planned performance and initiates corrective activity" (3:300). The integration of these two functions is seen by some as an important management function of the future (16:39).

This literature review will first address some of the basic concepts of planning and control as individual entities, then together as an integrated function of management. After which, the importance of planning and control relevant to information systems will be discussed. The literature review will end with a brief look at how these issues affect the information systems being procured under the Air Force Logistics Command's Logistic Management Systems Modernization Program.

Planning

Planning is vital to organizations for many reasons. Davis and Olson give three reasons for organizational planning: to focus the energies and activities of an organization, to settle the differences in objectives among subareas and individuals in the organization, and to lower the uncertainty about what the organization should do (3:300).

Planning occurs at each level of the organization. At the strategic level planning encompasses a broad time horizon, usually more than five years. Strategic planning deals with what function the organization will serve. At the tactical level, the time horizon for planning is shorter, generally between one and five years. Tactical planning deals with the implementation of strategic plans and more specifically the concerns of budgeting for capital expenditures. Operational planning deals with the shortest time horizon, between one and twelve months. At the operational level planners deal with the question of what is the most efficient way to implement the tactical plan and formulation of annual budgets (3:303).

Controlling

Controlling can be looked at as a three-step process consisting of measuring, evaluating, and correcting (9:224). Measuring consists of determining the progress being made

towards the accomplishment of organizational goals as determined in the planning process. Evaluating deals with analyzing the cause for variations from planned performance and potential corrective action. Correcting is the action taken to remedy an adverse trend (9:224-225). Control is often facilitated through the use of a management planning and control system.

Planning and Control

Bellaschi describes a planning and control system as "a continuous process of establishing plans by one's decision process and information system. Then, through control, adjustments are made, if necessary, to the plans or execution process by again utilizing the decision process and information system" (2:94).

Lorange and Scott Morton describe a more elaborate management control system. Their model is built on the following proposal (10:42):

> the fundamental purpose for management control systems is to help management accomplish an organization's objectives by providing a formalized framework for (1) the identification of pertinent control variables, (2) the development of good short-term plans, (3) the recording of the degree of actual fulfillment of short-term plans along the set of control variables, and (4) the diagnosis of deviations.

One of the interesting components of their model is their suggestion that "the linkage between the long-range planning

phase and the control phase is critical for the characterization of the control process" (10:53).

An example of a planning and control system used extensively by the Department of Defense for the acquisition of non-major contracts is the Cost/Schedule Status Report (C/SSR). Cost/schedule status reporting was developed to manage acquisition programs that were considered non-major, and therefore not covered by the DoD Cost Schedule Control Systems Criteria requirements. For DoD purposes, a non-major contract is a development contract under $25 million, or a production contract under $100 million (4:1-1).

AFLC Pamphlet 173-2, Cost/Schedule Management of Non-Major Contracts, lists the following purposes of the C/SSR (4:2-4):

(a) A clear description of the contract cost and schedule status at a given point in time.
(b) Early indicators of contract cost and schedule problems.
(c) Quantification, in the form of cost and schedule variances, of the problems and accomplishments being experiences.
(d) Identification of those WBS elements which are responsible for cost and schedule problems.
(e) Analysis of the impact if the individual problems on the contract.
(f) Trend information which can be used to estimate contract final costs.

From this list it may seem at first that C/SSR is just a controlling mechanism and not a part of the planning process. However, the establishment of a Work Breakdown Structure, the original cost estimates, and the

reprogramming that results due to variances link C/SSR to the planning process.

Planning and Control: Information Systems

Beyond the planning and control issues there are also issues that are specific to developing an information systems plan. Above all else, when planning for information systems it is vital that the information systems plan be compatible with, and based on the overall organizational plan (3:446). With the organization's strategic plan in mind, there are four major sections in developing an information systems plan (3:447).

1. Information System goals, objectives, and architecture.
2. Inventory of current capabilities.
3. Forecast of developments affecting the plan.
4. The specific plan.

Once a specific information systems plan has been developed, the organization must deal with the management of the procurement process.

Polis lists the following as the ingredients of successful management (14:72):

a thorough understanding of the work to be done;
a good contract, technically and managerially;
strong technical monitoring of the product;
and close monitoring of contractual terms and conditions.

Underlying Polis' recommendations is a theme that was present in much of the literature that dealt with planning of information systems: The idea that the planning for, and

implementation of information systems took a consolidated

effort from a cross section of the entire organization

(15:52)(14:173)(3:447).

Planning and Control: AFLC LMS Modernization Program

Many of the planning and controlling concepts and

information systems specific issues can be seen in the Air

Force Systems Command's Logistics Management Systems

Modernization Program. The modernization program is an

effort to upgrade the command's aging and obsolete computer

systems (13:1). Prior to the LMS Modernization Program

"Management Information Systems (MIS) developments in AFLC

had been done by the major functional organization. . . .

There was no standardized, central management of overall MIS

acquisition" (13:2). The LMS Modernization Program brought

information systems planning more in line with the Command's

overall strategic plan and provided the necessary planning

and controlling mechanisms to manage the acquisition of the

new information systems. It is the data generated from the

systems acquired under this modernization program that this

research will be conducted on.

III. Methodology

Population

The population for this study is the cost data for information systems being acquired under the AFLC Logistics Management Systems Modernization Program which use cost reporting techniques.

Sample

The sample consists of a census of all available cost data through January 1988.

Definition of Variables

The following variable definitions come from the Standard Work Breakdown Structure (WBS) and Dictionary for Acquisition of Logistics Management Systems Modernization Programs (4:6-17). The variables coincide with the second level of the Work Breakdown structure.

Management (MGMT). This includes control throughout the five phases of program acquisition. These five phases are conceptual, definition, development, test, and operation.

System Engineering (SYEN). The system engineering element refers to the technical and management efforts of directing and controlling a totally integrated engineering

effort of a system program. This element encompasses the systems engineering effort to define the system and the integrated planning and control of the technical program efforts of design engineering, logistics engineering, specialty engineering, production engineering, and integrated test planning.

Hardware (HARD). Hardware refers to a machine or group of interconnected machines consisting of input, storage, computing, control, and output devices which use electronic circuitry in the main computing element to automatically perform arithmetic and/or logical operations by means of internally stored or externally controlled program instructions.

Software (SOFT). Software refers to those program and routines consisting of a deck of punch cards, magnetic or paper tapes, read-only memory (ROM) units (plug in type) or other physical medium containing a sequence of instructions and data in a form suitable for insertion into the computer and used to direct the computer to perform a desired operation or sequence of operations.

Communications (COMM). The communications network refers to that equipment used to receive and transmit messages of data from a host computer to another computer or from one person or place to another. This equipment includes transmitter, receiver, terminal equipment, internal

facility trunking, modem, cryptographic equipment, power supply, and interface software equipment.

Facilities (FAC). This activity includes planning, construction, conversion, power and environmental systems, and site inspections.

Test/Evaluation (TNE). The test and evaluation element refers to the use of prototype, production, or specially fabricated hardware to obtain or validate engineering data on the performance of the electronics system. This element includes the detailed planning, conduct, support, data reduction and reports from such testing.

Data/Documentation (DATA). This data element refers to all deliverable data as listed on a Contract Data requirements list. This elements includes only such effort that can be reduced or will not be incurred if the data item is eliminated.

Training (TRAN). The training element refers to training services, devices, accessories, aids, equipment, and parts used to facilitate instruction through which personnel will acquire sufficient concepts, skills, and aptitudes to operate and maintain the system with maximum efficiency.

Implementation (IMP). This activity consists of installing, converting and evaluating hardware and/or software systems.

Maintenance (MAIN). This activity consists of software maintenance, software update, maintenance transfer, hardware repair, and hardware update.

Additional variable definitions for this research are derived from the Department of Defense Instruction 7000.10, Contract Cost Performance, Funds Status and Cost/Schedule Status Reports (7:4).

Budgeted Cost Work Scheduled (BCWS). The value of all work to scheduled to be accomplished as of the reporting cut-off date.

Budgeted Cost Work Performed (BCWP). The value of all work accomplished as of the reporting cut-off date.

Schedule Variance (SV). The difference between the BCWS and BCWP.

Cost Variance (CV). The difference between BCWP and ACWP.

Budget at Completion (BAC). The total of all budgeted costs.

Estimate at Completion (EAC). The actual cost to date plus the latest estimate of cost for the remaining work.

The final variable definition is:

Month. The number of months that have elapsed since the date on which work began on a contract and the reporting cut-off date.

All of the variables listed are interval or better.

Developing the Model

Data Manipulation. The first step in developing the model was to manipulate the data so that it was in a uniform format for all of the observations. Although the contracts required a standard WBS, contractors used different conventions in reporting their data. Most notable of the discrepancies in reporting conventions was the treatment of General and Administrative expenses. In some cases contractors separated out General and Administrative expenses as a separate item, while others reported it as part of the individual cost areas. This was remedied by applying General and Administrative expenses back to individual cost areas based on a ACWP for each area divided by the total ACWP for the entire contract. Other similar reporting discrepancies were handled in the same manner.

Dependent Variable. Once the data was in a uniform format, it was necessary to develop a quantitative measure of contract performance that would be descriptive of contract performance regardless of the size of the contract. The measure used was Contract Performance Factor (CPF). The CPF was determined for each observation by dividing the Estimate at Completion by the Budget at Completion.

Contract Performance Factor:

Estimate at Completion/Budget at Completion

For a contract that is currently scheduled to be completed at the budgeted price, the CPF would be equal to one. If

the contract is scheduled to be completed under the budgeted cost, the CPF would be less than one. If the contract is scheduled to be completed over the budgeted cost, the CPF would be greater than one.

Independent Variables. The independent variables are a measure of the costs of each of the 11 cost areas identified in the standard WBS. The measure used is a weighted cost variance. The weighted cost variance consists of the cost variance multiplied by the percentage of money spent on the specific cost area.

Weighted Cost Variance:

$$(BCWPXXXX-BCWSXXXX) * (ACWPXXXX/ACWPTOTAL)$$

Where XXXX is the individual cost area

The weighted cost variance was calculated for each of the 11 cost areas and used as the independent variable for each respective area.

Initial Model. Once the dependent and independent variables were defined each of the cost areas were included in an initial prediction model.

$$E(Y) = B_0 + B_1X1 + B_2X2 + B_3X3 + B_4X4 + B_5X5 + B_6X6 +$$
$$B_7X7 + B_8X8 + B_9X9 + B_{10}X10 + B_{11}X11$$

Where:

```
E(Y)  =  CPF
X1   =  Management
X2   =  System Engineering
X3   =  Hardware
X4   =  Software
X5   =  Communication
```

```
X6  =  Facilities
X7  =  Test and Evaluation
X8  =  Data
X9  =  Training
X10 =  Implementation
X11 =  Maintenance
```

Validating and Transforming the Model

After the initial model was defined it was necessary to check the model validity by determining if the model assumptions are met. The assumptions are made about the error, or residuals values, of the model (11:407).

Assumption One: The mean of the probability distribution of error is zero.

Assumption Two: The variance of the probability distribution of the error is constant.

Assumption Three: The probability distribution of the error is normal.

Assumption Four: The errors associated with any two different observation are independent.

These assumptions were initially checked by using a residual analysis and by examining scatter plots of the each independent variable plotted against the dependent variable. Needed corrections were made to the initial model by applying transformations to the model variables when appropriate.

Reducing the Model

The final step was to take the transformed model and reduce it to only those variables that added significantly to the usefulness of the model. (A level of significance of .05 was established as a threshold for eliminating independent variables.) The resulting reduced model was once again checked for compliance with model assumptions.

IV. Findings and Analysis

Model Analysis

In Chapter Three the initial model was defined as
$E(Y) = B_0 + B_1X1 + B_2X2 + B_3X3 + B_4X4 + B_5X5 + B_6X6 + B_7X7 + B_8X8 + B_9X9 + B_{10}X10 + B_{11}X11.$
A regression was performed using this model with the SAS Statistical Package. (All statistical procedures were performed using SAS). The results are in Table 1.

From the initial regression it appears that the model is useful in determining the contract performance factor. The coefficient of determination, R^2, implies that 77.05% of the variation in CPF can be accounted for by the model. The results of the global F test show that the observed significance level, or p-value, is .0001 indicating a strong probability that at least one of the model coefficients is nonzero, and therefore useful in predicting the CPF.

Independent Variables

Looking at the independent variables individually, however, it appears that some of the variables are not useful in determining CPF. P-values range from less than .0001 for Software and Communication, to .8640 for Facilities. Further analysis is required to determine which variables to eliminate from the model.

```
DEP VARIABLE: CPF

                        ANALYSIS OF VARIANCE

                         SUM OF        MEAN
       SOURCE     DF     SQUARES      SQUARE    F VALUE    PROB>F

       MODEL      11   2.98411872  0.27128352   22.583    0.0001
       ERROR      74   0.88893365  0.01201262
       C TOTAL    85   3.87305237

            ROOT MSE      0.1096021    R-SQUARE        0.7705
            DEP MEAN      1.107393     ADJ R-SQ        0.7364
            C.V.          9.897304

                        PARAMETER ESTIMATES

                     PARAMETER  STANDARD   T FOR H0:
       VARIABLE   DF  ESTIMATE   ERROR   PARAMETER=0   PROB>|T|

       INTERCEP    1    1.04077290  0.01664065   62.544    0.0001
       MGMT        1   -0.000167102 0.000251699  -0.664    0.5088
       SYEN        1    0.0003200166 0.001144086   0.280    0.7805
       HARD        1    0.0002256927 0.000393590   0.573    0.5681
       SOFT        1   -0.000979722 0.00007874  -12.442    0.0001
       COMM        1    0.02694098  0.01014784    2.655    0.0097
       FAC         1    0.002149505 0.01250417    0.172    0.8640
       TNE         1   -0.000122489 0.00014070   -0.871    0.3868
       DATA        1   -0.00182469  0.00633565   -0.288    0.7741
       TRAN        1   -0.0154405   0.007497     -2.060    0.0430
       IMP         1   -.0000472383 0.00015290   -0.309    0.7582
       MAIN        1    -0.270167   0.06562655   -4.117    0.0001
```

Table I: Regression Results -- Initial Model

Initial Transformations

An examination of the residual plots and scatter plots
for each of the independent variables proved inconclusive at
this point in the data analysis (Appendix A). Clearly
random residual plots were not obtained due to the limited
number of observations available. Because of the constraint

imposed by the limited amount of data that has been reported
on the contracts to date, the residual plots were examined
to see if any patterns would clearly indicate violations of
the model assumptions. The scatter plots were also examined
to look for clues to possible transformations that could
improve the model. Ultimately, each independent variable
was individually transformed using each of the following
transformations:

$$x = 1/x \quad x = x^2 \quad x = x^3 \quad x = \log x \quad x = x^{1/2}$$

where x = an independent variable

The results for some of these transformations were undefined
due to the value of x being equal to zero in some instances.
In other cases, where the transformation resulted in real
values, the transformed variables failed to show any
improvement in the model. In only one case did the
transformation process achieve positive results: the
transformation of the independent variable Software.

Software. The independent variable software had a
level of significance in the initial regression of .0001.
In addition to this an examination of the scatter plot and
residual plot indicated that a transformation might be
appropriate. After several different transformations were
tried, squaring the independent variable software was chosen
as the most effective. A new regression was run using a
single independent variable: the weighted cost variance of
software costs squared (SOFTS). The results are in Table 2.

21

```
DEP VARIABLE: CPF

                  ANALYSIS OF VARIANCE

                    SUM OF        MEAN
SOURCE      DF      SQUARES       SQUARE    F VALUE   PROB>F

MODEL        1    2.98900240   2.98900240  284.007   0.0001
ERROR       84    0.88404997   0.0105244
C TOTAL     85    3.87305237

         ROOT MSE      0.1025885    R-SQUARE    0.7717
         DEP MEAN      1.107393     ADJ R-SQ    0.7690
         C.V.          9.263964

                  PARAMETER ESTIMATES

                  PARAMETER    STANDARD     T FOR H0:
VARIABLE DF       ESTIMATE       ERROR   PARAMETER=0  PROB>|T|

INTERCEP  1      1.04770724   0.01161552    90.199     0.0001
SOFTS     1     .00000191304  1.13517E-07   16.853     0.0001
```

Table II: Software Regression Results

The new regression run with single transformed variable,
software squared, has a coefficient of determination, R^2, of
77.17%. This is slightly higher than the R^2 value for the
initial regression that had included all of the variables.
An examination of the scatter plot, (see Appendix B), shows
that the relationship between CPF and the transformed
independent variable Software approximates a linear
relation. Examining the Residual Plots shows an improvement
over those plotted from the initial regression that
contained all of the variables. Because of the relatively
small number of observations on which the analysis is based,

it is difficult to determine with certainty whether the plots indicate that the model assumptions have been met.

Transformed Model

A new regression was run with all of the original independent variables. This time, however, the software variable was transformed to Software Squared. The results are found in Table 3.

The results of the transformed model show a slight improvement over the original. The new rsquare value indicates that now 82.63% of the variation of CPF can be attributed to the independent variables.

Reducing the Model

The discussion on the independent variables stated that some of the variables should be removed from the model. The transformed model was screened using the SAS STEPWISE procedure. The summary of the results are found in Table 4, and the complete procedure is found in Appendix C.

DEP VARIABLE: CPF

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	11	3.20032645	0.2909387	32.003	0.0001
ERROR	74	0.67272592	0.00909089		
C TOTAL	85	3.87305237			

ROOT MSE	0.09534616	R-SQUARE	0.8263
DEP MEAN	1.107393	ADJ R-SQ	0.8005
C.V.	8.609963		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB>|T|
INTERCEP	1	1.0513428	0.01421243	73.973	0.0001
MGMT	1	-0.00015337	0.00021897	-0.700	0.4859
SYEN	1	-0.00049219	0.00099812	-0.493	0.6234
HARD	1	0.000164409	0.00034218	0.480	0.6323
SOFTS	1	.0000017863	1.1821E-07	15.111	0.0001
COMM	1	0.0166434	0.00891099	1.868	0.0658
FAC	1	0.00793536	0.01086976	0.730	0.4677
TNE	1	-0.00011940	0.00012238	-0.976	0.3324
DATA	1	0.00273444	0.00557019	0.491	0.6249
TRAN	1	-0.011849	0.00655682	-1.807	0.0748
IMP	1	-.000097222	0.00013267	-0.733	0.4660
MAIN	1	-0.2195	0.05784135	-3.796	0.0003

Table III: Regression Results -- Full Model

The STEPWISE procedure narrowed the original eleven independent variables down to five: Software Squared, Maintenance, Communication, Training, and Test and Evaluation.

```
                       SUMMARY OF
STEPWISE REGRESSION PROCEDURE FOR DEPENDENT VARIABLE CPF

              VARIABLE NUMBER  PARTIAL  MODEL
STEP ENTERED  REMOVED    IN     R**2    R**2    C(P)

  1  SOFTS             1    0.7717   0.7717  15.2457
  2  MAIN              2    0.0117   0.7835  12.2404
  3  COMM              3    0.0174   0.8009   6.8268
  4  TRAN              4    0.0075   0.8084   5.6214
  5  TNE               5    0.0109   0.8193   2.9816

              VARIABLE
 STEP  ENTERED  REMOVED        F                PROB>F

  1   SOFTS              284.0068           0.0001
  2   MAIN                 4.5039           0.0368
  3   COMM                 7.1665           0.0090
  4   TRAN                 3.181C           0.0782
  5   TNE                  4.8218           0.0310
```

Table IV: Summary of STEPWISE PROCEDURE

Although this was a marked improvement from the eleven independent variable in the original model, the model that the STEPWISE procedure suggested, had a Mallow's Cp value of 2.9816. For a model with six parameters, this value indicates a great deal of bias. Therefore, the analysis was continued in search for a better model. In order to do this, all possible subset models were considered using the SAS RSQUARE procedure. The results are presented in Appendix D.

In addition to providing the rsquare value, The RSQUARE procedure also reports the value of Mallow's Cp for all possible models. The value of Mallow's Cp measures the
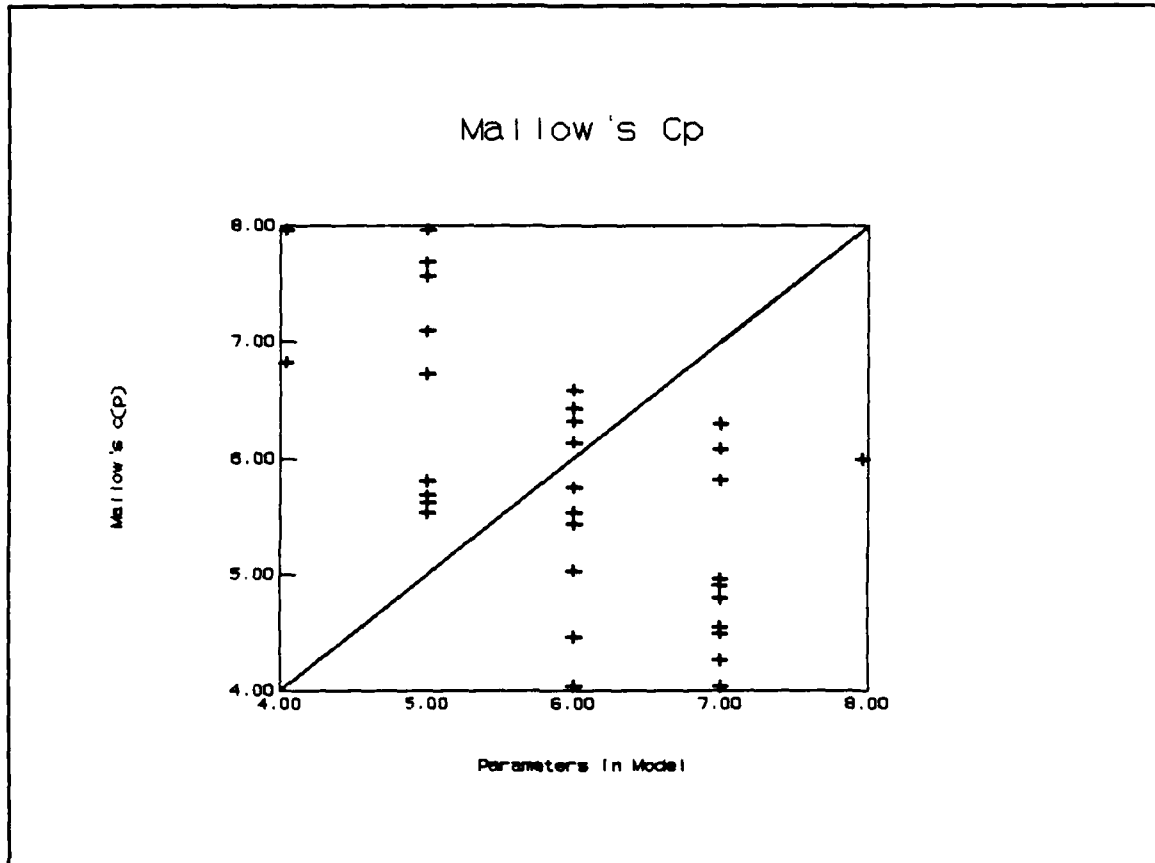
Figure 1: Plot of Mallow's Cp

precision of the prediction model by taking into account the
bias of the model. Values of Cp that are close to the
number of parameters in the model have less bias than models
that have a Mallow's Cp value that varies significantly from
the Cp value. Graphically, these values lie close to the
line in Figure 1. Based on the results of the RSQUARE
procedure, two models were selected for further
consideration. These models were selected by looking at
both their R^2, and the Cp values.

The first of these models contains five independent
variables: Software Squared, Facilities, Test and

26

Evaluation, Training, and Maintenance. The R^2 for this model is .8128 and the Cp is 5.747. The second model contains four independent variables: Software Squared, Test and Evaluation, Training, and Maintenance. The R^2 for this model is .8086 and the Cp is 5.5302. The complete regression results of each of these models are found in Appendices E and F.

The first step in distinguishing between these two models is by comparing their adjusted rsquare values. The five variable model has an adjusted rsquare of .8011. The four variable model has an adjusted rsquare of .7992. This seems to indicate that the five variable model is better able to predict the CPF. Looking at the variables individually, the five variable model, contains a variable with a p-value of .1849 (Facilities). This is above the threshold established in the methodology for eliminating a variable. Before eliminating the Facilities variable, a regression on the five variable model was performed and a partial f-test comparing it to the 4 variable model. The results are in Appendix G. The results (F-value=1.788 and corresponding p-value of .1849) indicate that at a level of alpha = .05 the null hypothesis that the beta value for Facilities is zero cannot be rejected. Based on this F-test, and the p-value, the Facilities variable was eliminated from the model and the four variable model was chosen.

The following is the resulting model:

CPF =

1.04644+.00000184SOFTS-.00021672TNE-.0158107TRAN-.134643MAIN

The residuals were once again plotted to check for model assumptions and look for possible transformations (See Appendix H). The residual plots again seemed inconclusive as to the satisfying of model assumptions due to the limited data availability. Three transformations were performed to see if the model could be improved:

$$1/CPF \qquad LogCPF \qquad CPF^{1/2}$$

In each instance, there was a decrease in the rsquare value and no noticeable improvement in the random nature of the residual plots. Therefore the four variable model was not transformed.

Model Significance

The level of significance for the variables range from .0001 to .0230. The individual p-values are as follows:

Software Squared	.0001
Test and Evaluation	.0230
Training	.0084
Maintenance	.0011

When looking at the significance of the model it is important to point out that the value of the model is not found in the exact Beta values of the model parameters.

Instead, it is important to look at which variables were included in the model.

Research Objectives

In Chapter One, the following research objectives were established:

(1) to identify what indicators can be used to more efficiently control of information systems costs and (2) to build a prediction model around these indicators.

In response to the first objective, the weighted cost variance of Software, Test and Evaluation, Training, and Maintenance are key indicators of overall contract performance.

As for the second research objective, the prediction model for the Contract Performance Factor can be used for predicting contract cost performance, but that is not where the real worth of the model lies. Instead, by looking at the model, acquisition managers can focus on costs associated with the key variables the model identifies in order to better control the acquisition of information systems.

V. Conclusion and Recommendations

Practical Implications

When looking at the practical implications of this research it is important to realize that the specific model developed is limited in its ability to be generalized to other populations. However, there are a number of things that can be taken from this research and universally applied. One of the important steps in developing a methodology was to come up with ratio type performance indicators. The dollar value of the contracts in the analysis differed significantly. Therefore it was necessary to have a measure that meant the same thing regardless of the size of the contract. The Contract Performance factor did just that. Regardless of the size of the contract, the Contract Performance Factor provides a measure that readily identifies the performance of a contractor.

The next item of importance in the methodology was finding a way to measure the importance of each cost area taking into consideration both the contract size, and the amount of money allocated to the cost area. The weighted cost variance accomplished both these things. In addition to developing ratio type measures for the model variables, identifying key variables is also a vital issue.

The management of the acquisition of information
systems is a complex task. The idea of identifying key
variables to focus on when monitoring contractor progress
can significantly improve a program manager's effectiveness.
It is interesting to note that the indicators that were
identified in this analysis were all intangible in nature.
The variables that were eliminated were either tangible
things, like hardware or facilities, or they were intangible
areas that have been in existence for quite some time, for
example management and systems engineering. This might
indicate that as experience is gained in an area it has less
impact on contract performance. Conversely, the performance
in areas that are still relatively new, or difficult to
quantify, have a greater impact on contractor performance.

Policy Implications

The goal of this research is not to provide a
definitive model that will help program managers to predict
contractor performance. Instead, the goal is to establish
procedures, or motivation, for program managers to identify
key control variables that will help them to manage their
programs more effectively in a time of austere budgets and
restricted manpower availability.

Reccmmendations

At the time this research began, the cost data for programs under the LMS were just beginning to be compiled. Some contractors were having difficulty in complying with the C/SSR reporting requirements and other contracts were not yet on cost type contracts. Because of this, the available data was limited, and some if it was unusable due to unreliability. It is recommended that the data be recompiled and the methodology repeated with a larger data base. The availability of a larger sample would be extremely useful in improving the reliability of the model and the determination of the variables to include.

An analysis of the types of variables that are selected for inclusion in future models would also be beneficial. The answers to questions like: Are intangible cost areas more significant in determining contractor performance? or does experience in a specific cost area lessen its impact on contract performance? Finding the answer to this type of questions can improve the efficiency and effectiveness of program managers.

Appendix A: <u>Scatter Plots and Residual</u>
<u>Plots for independent Variables</u>
<u>in the Initial Regression Model</u>
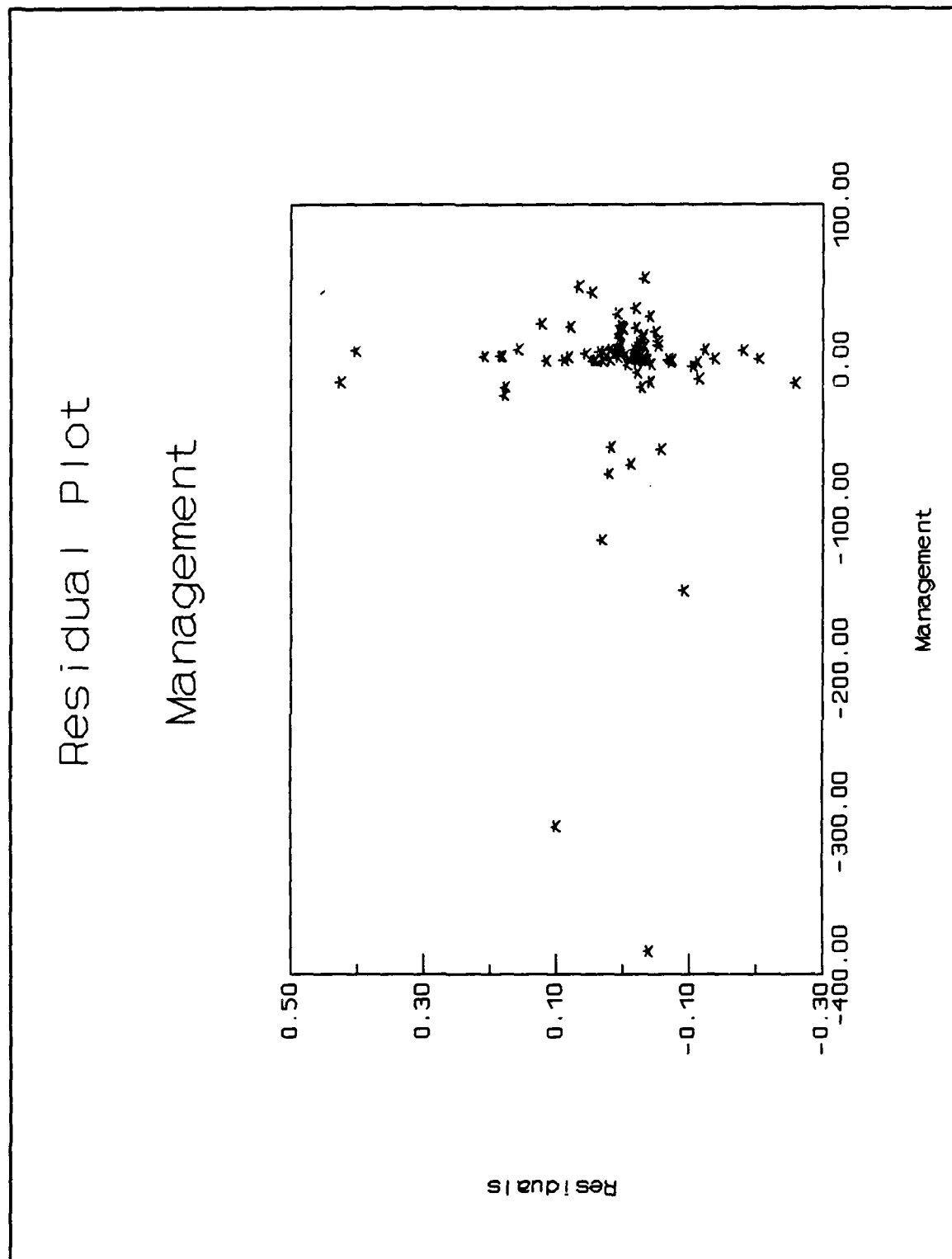
Figure 2: Residual Plot -- MGMT
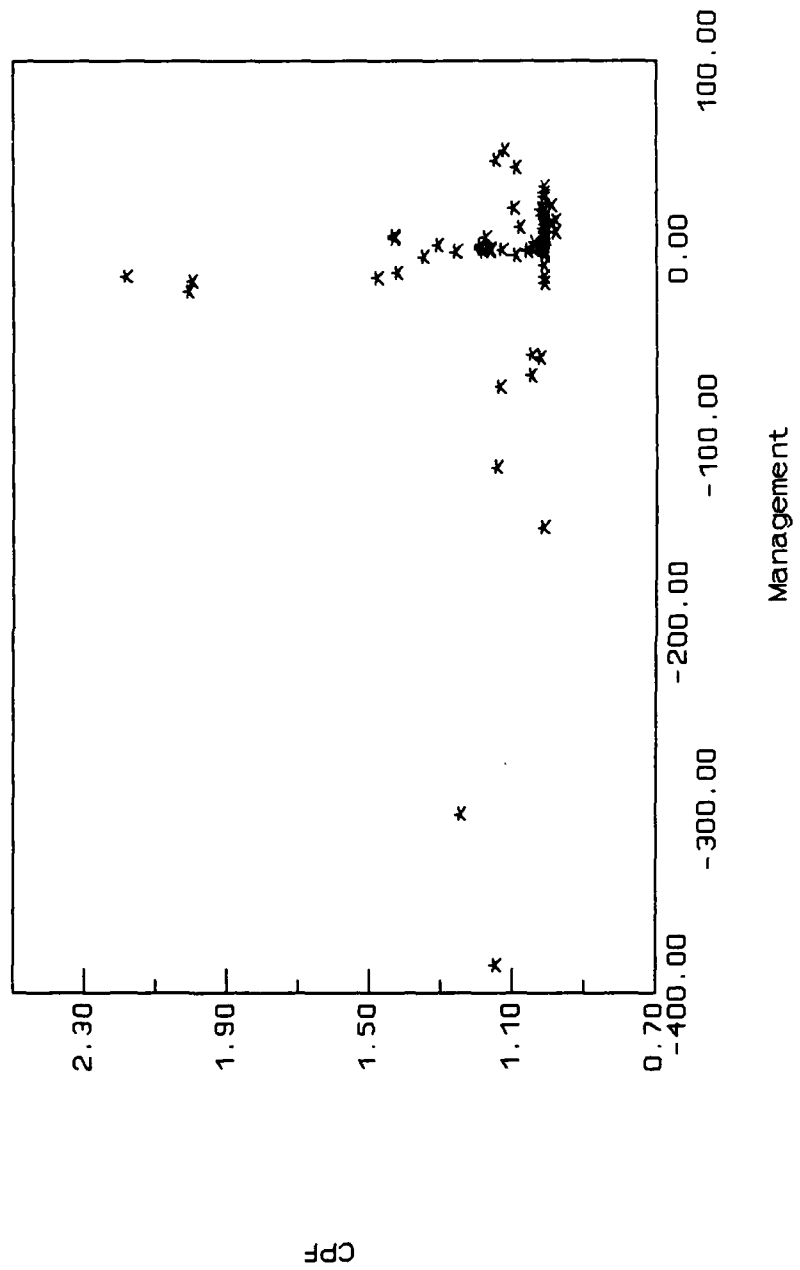
Figure 3: Scatter Plot -- MGMT

Figure 4: Residual Plot -- SYEN

Scatter Plot

System Engineering
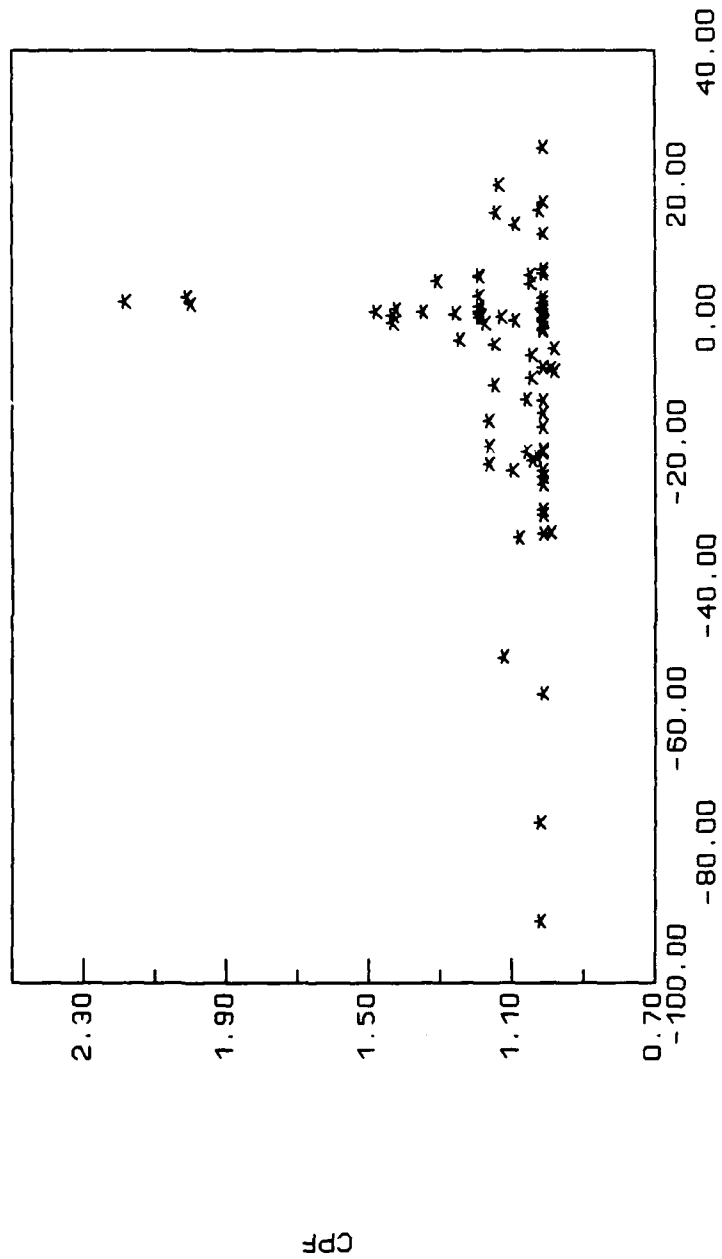
Figure 5: Scatter Plot -- SYEN

37
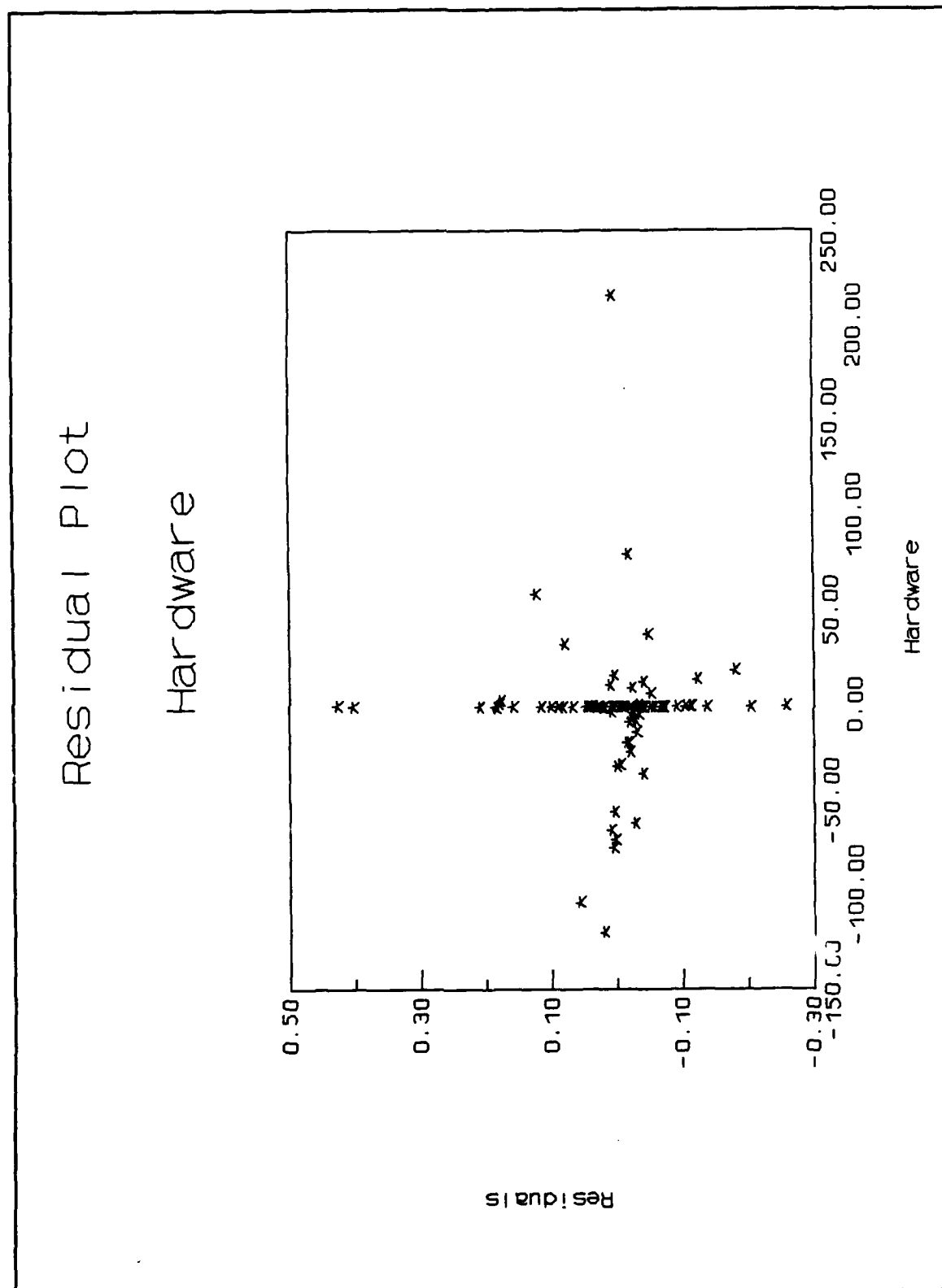
Figure 6: Residual Plot -- HARD

Scatter Plot

Hardware
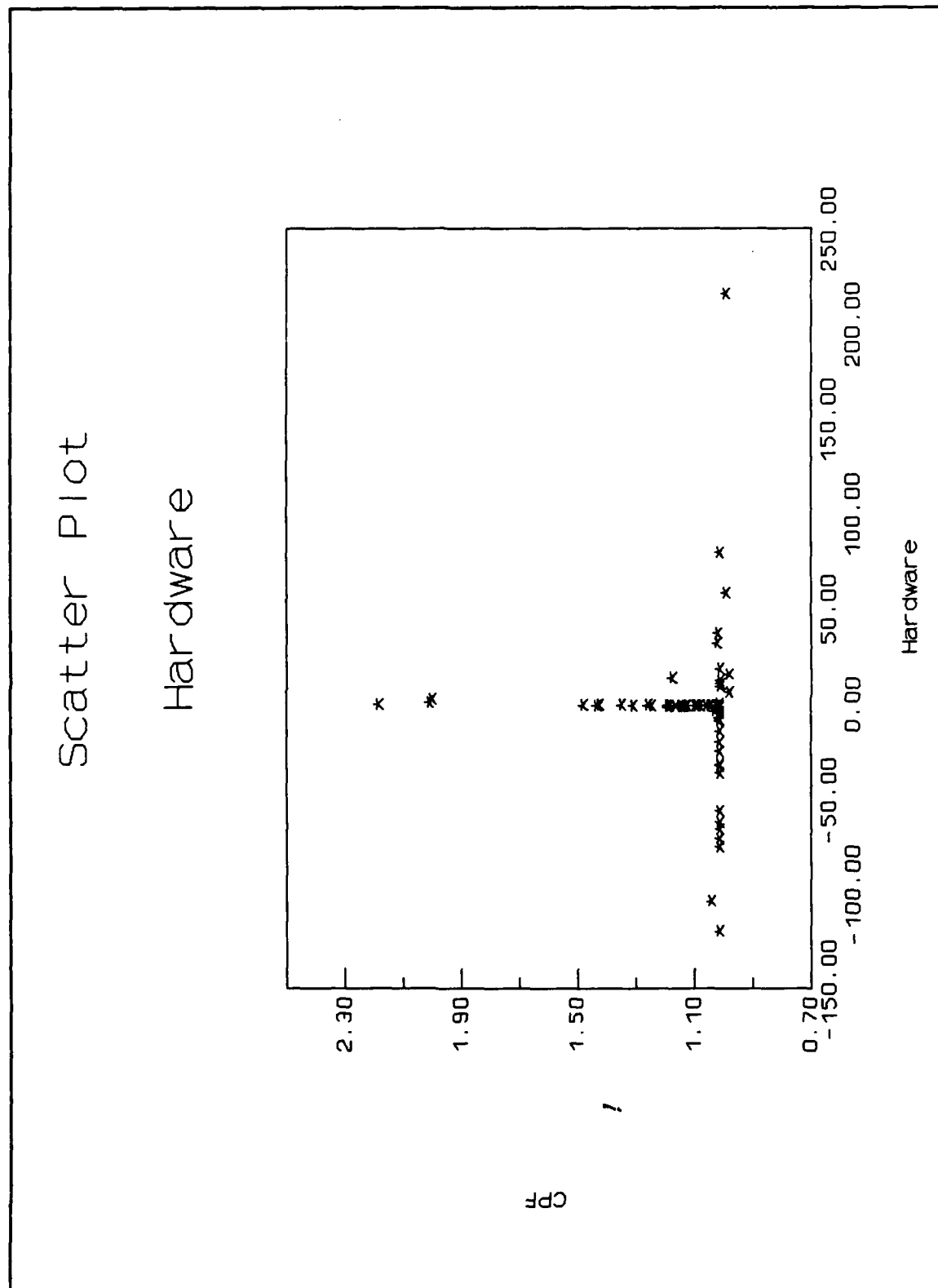
Figure 7: Scatter Plot -- HARD

39
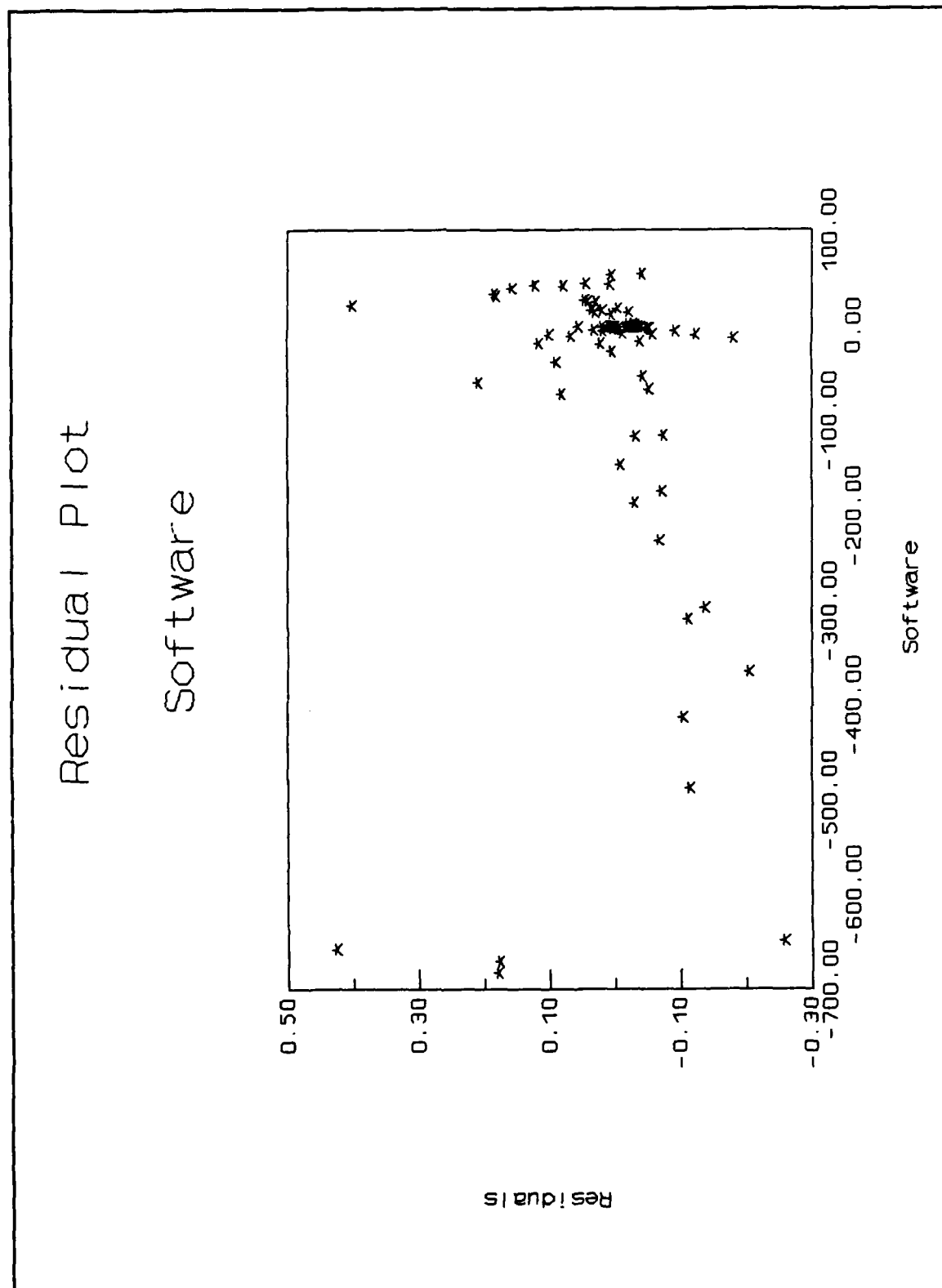
Figure 8: Residual Plot -- SOFT

Scatter Plot

Software
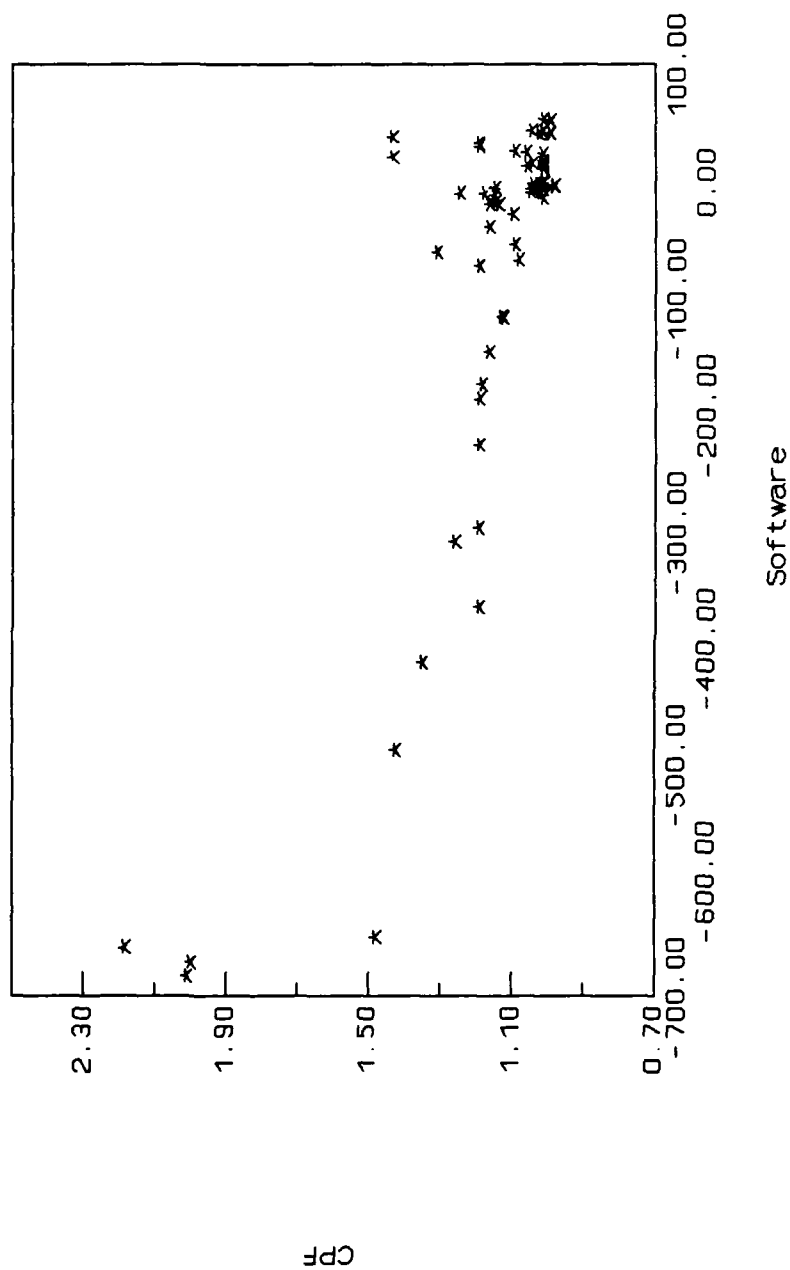
Figure 9: Scatter Plot -- SOFT
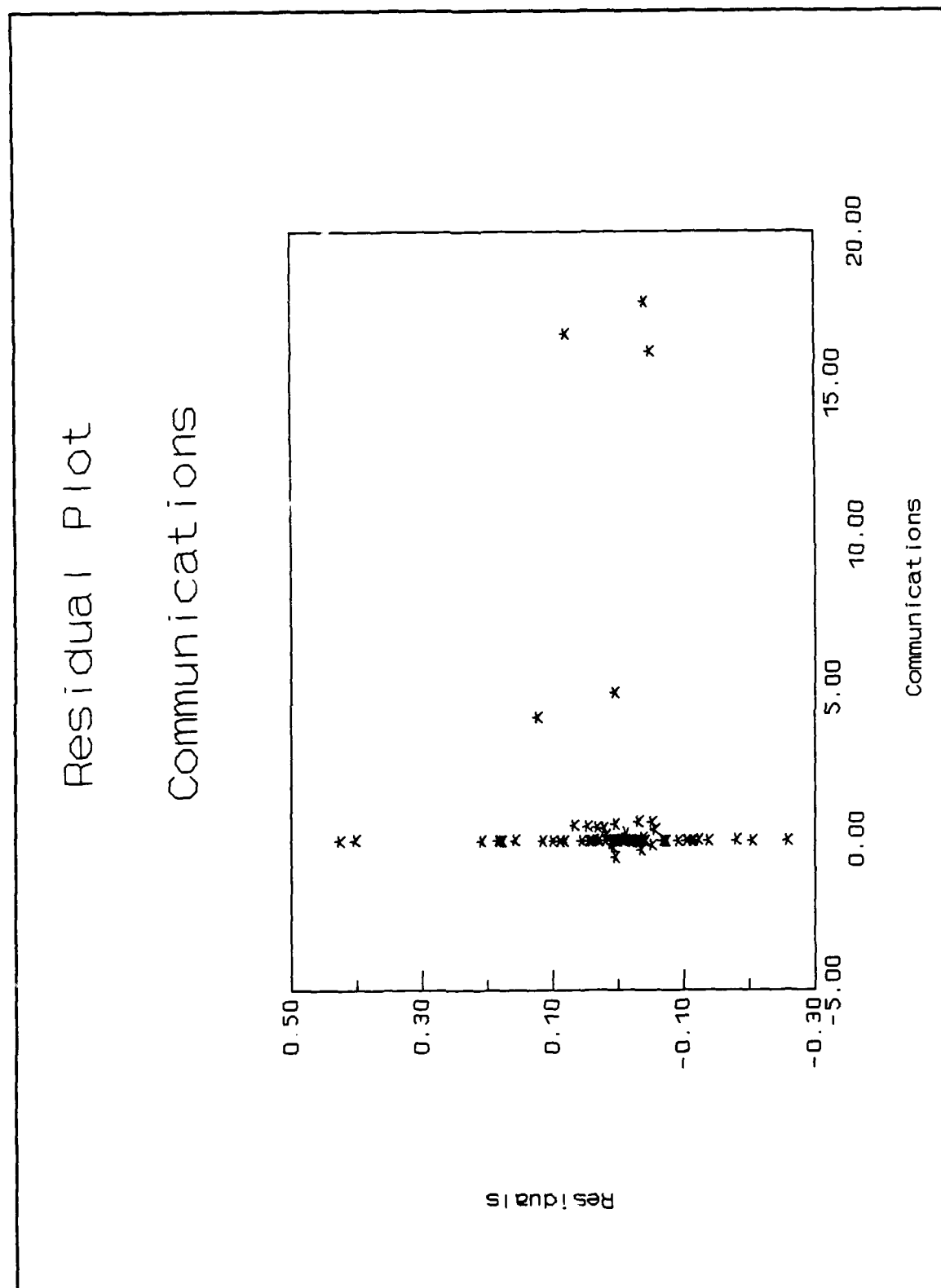
Figure 10: Residual Plot -- COMM
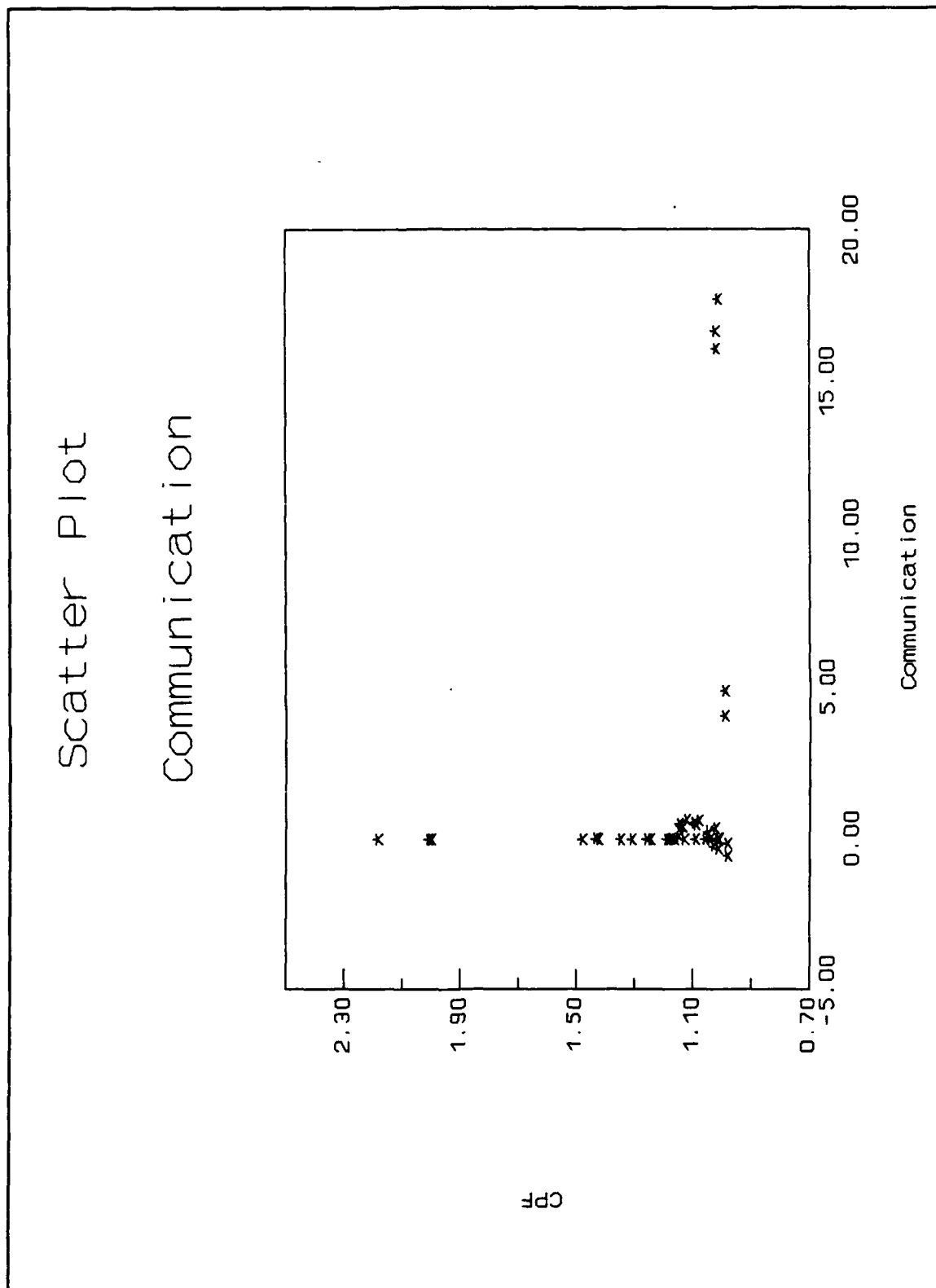
Figure 11: Scatter Plot -- COMM
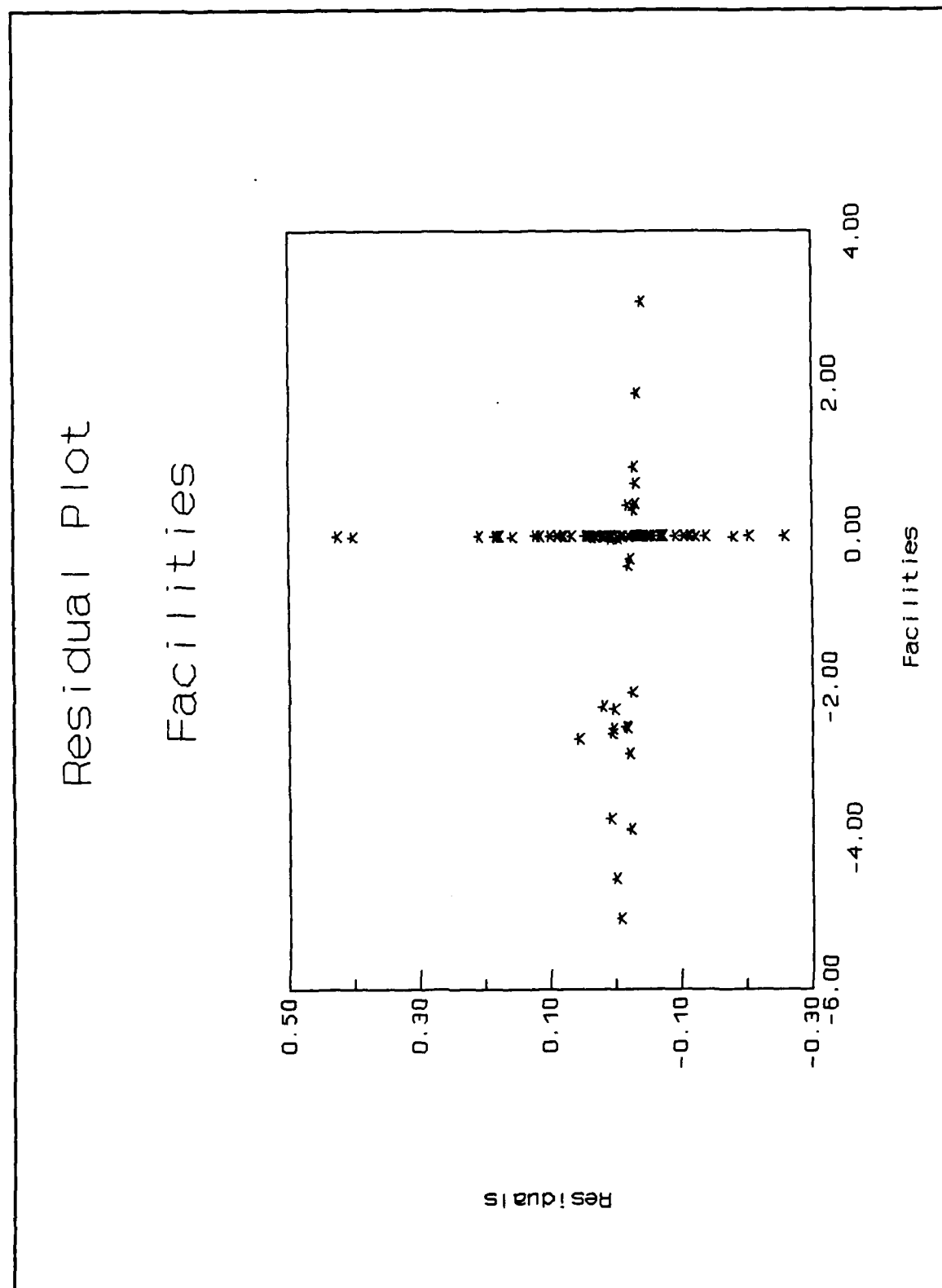
Figure 12: Residual Plot -- FAC
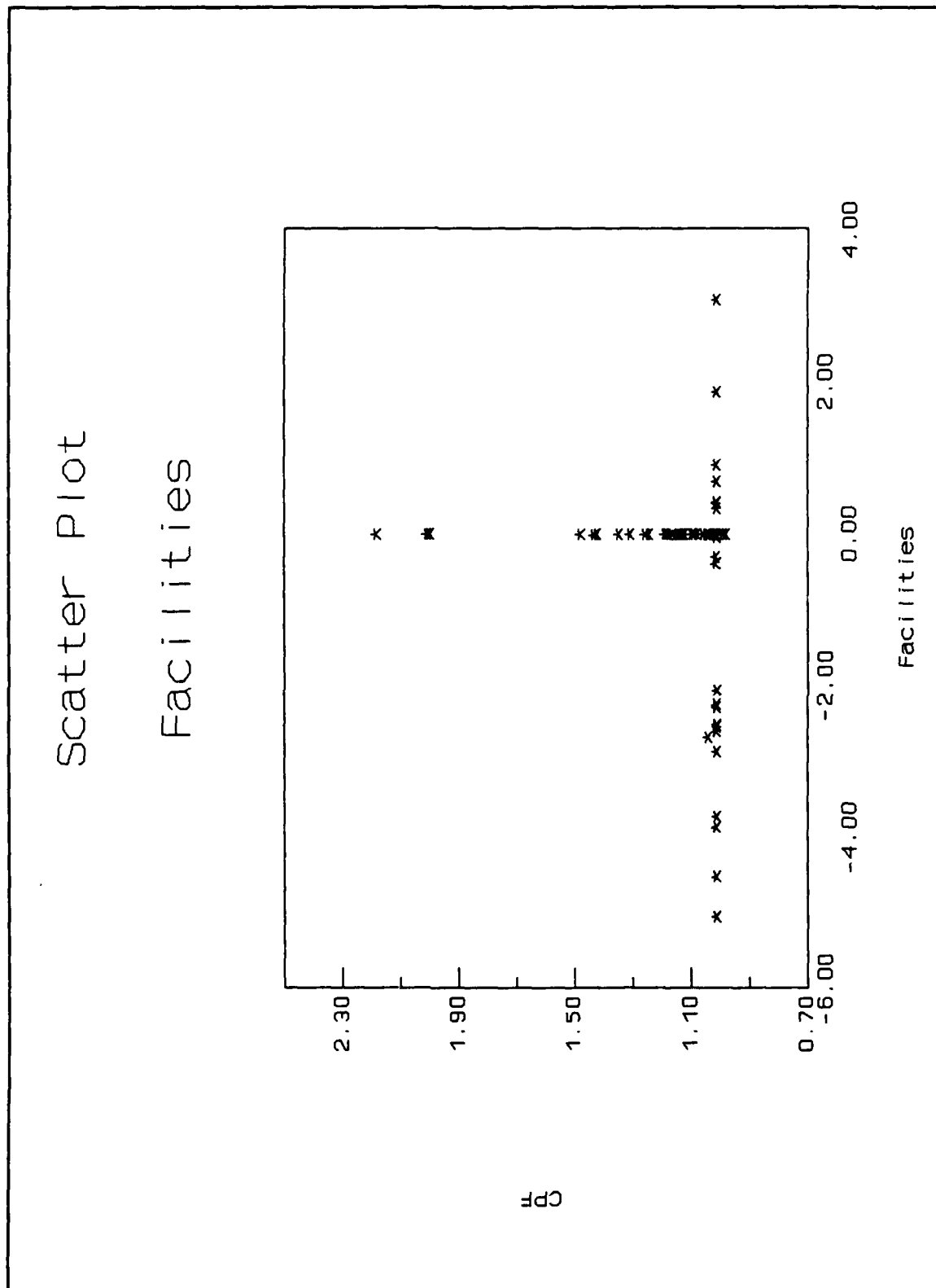
Figure 13: Scatter Plot -- FAC

45

Figure 14: Residual Plot -- TNE

Scatter Plot

Test & Evaluation

CPF

Test & Evaluation
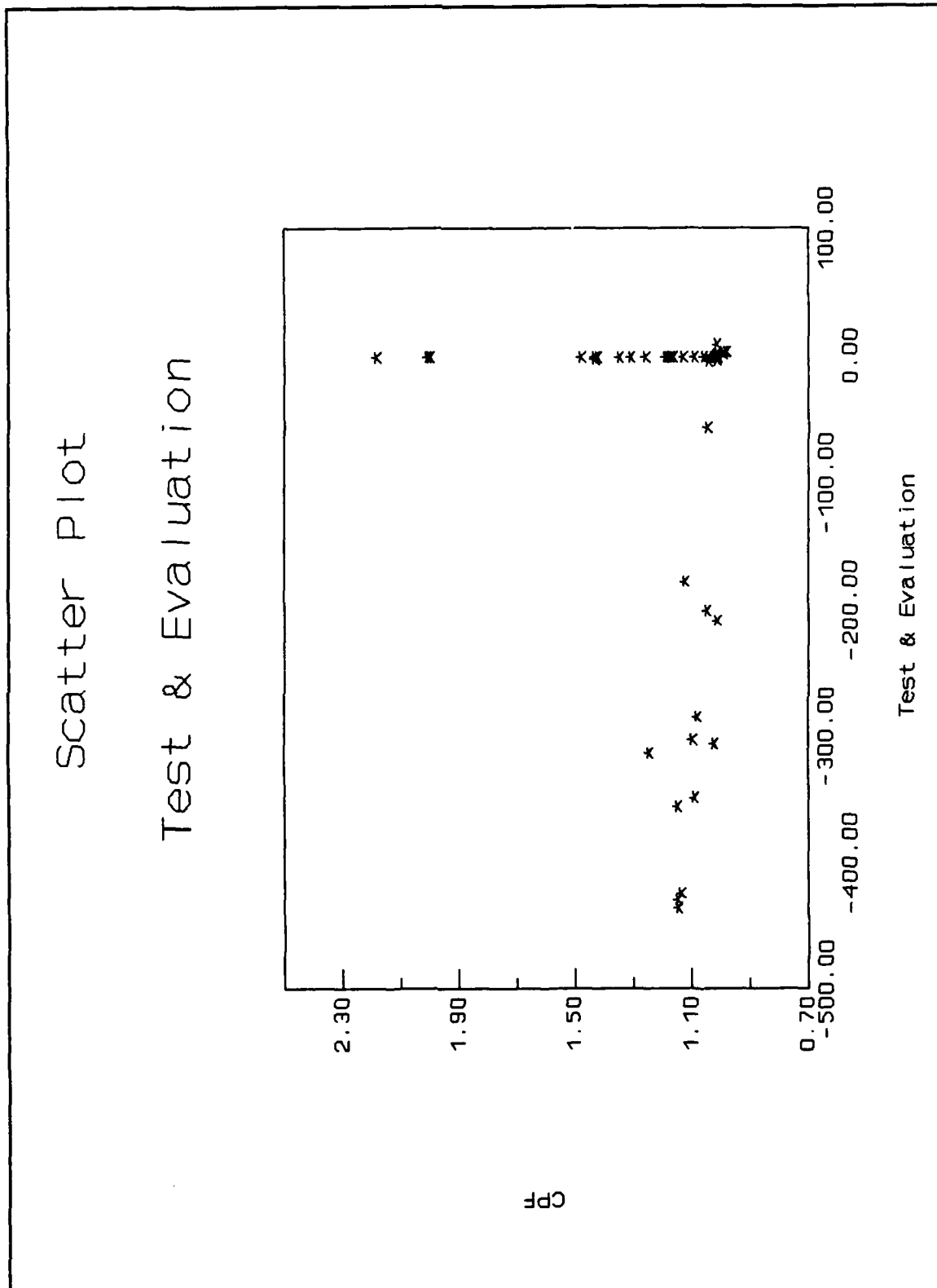
Figure 15: Scatter Plot -- TNE
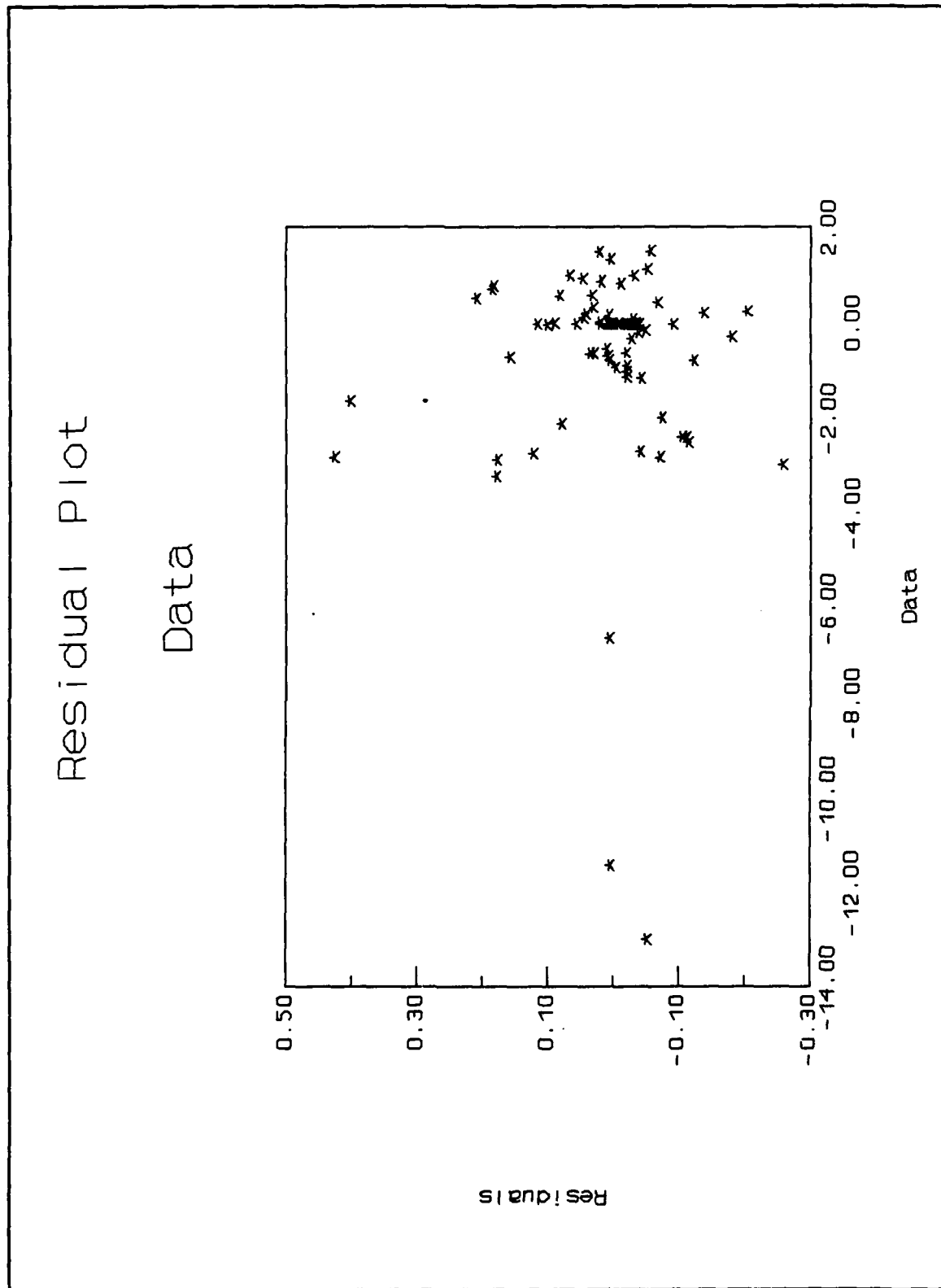
Figure 16: Residual Plot -- DATA

48
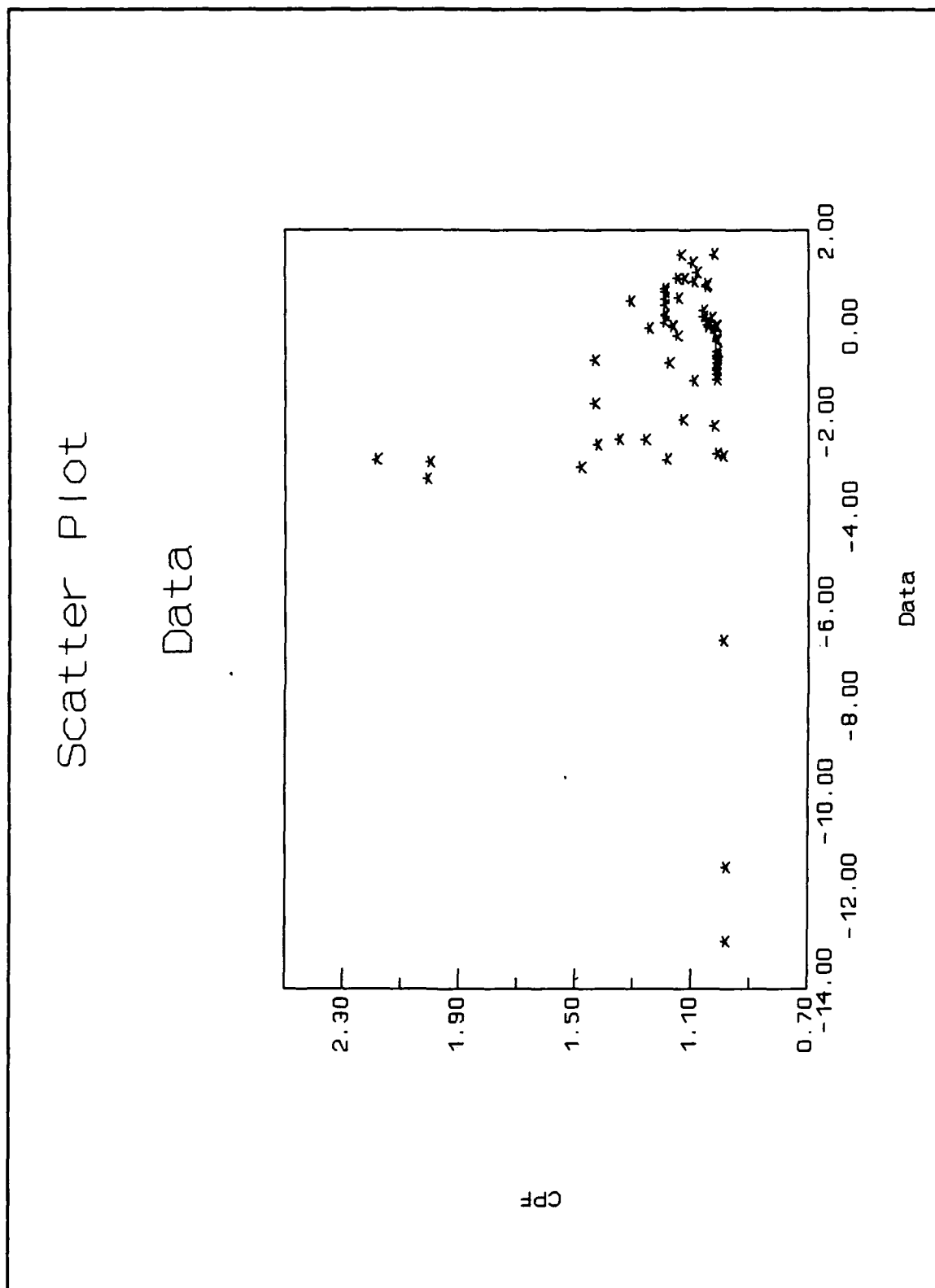
Figure 17: Scatter Plot -- DATA

49
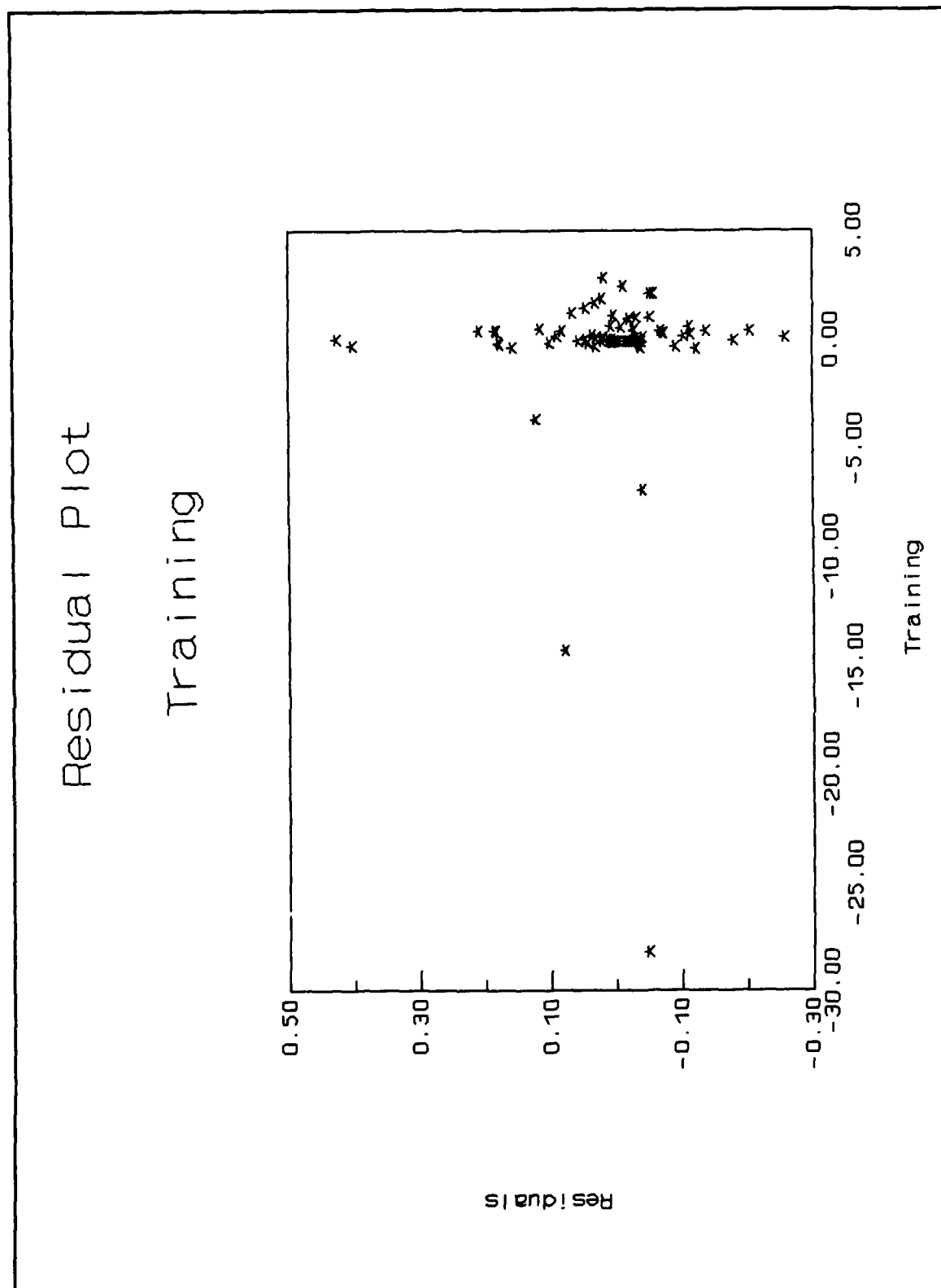
Figure 18: Residual Plot -- TRAN
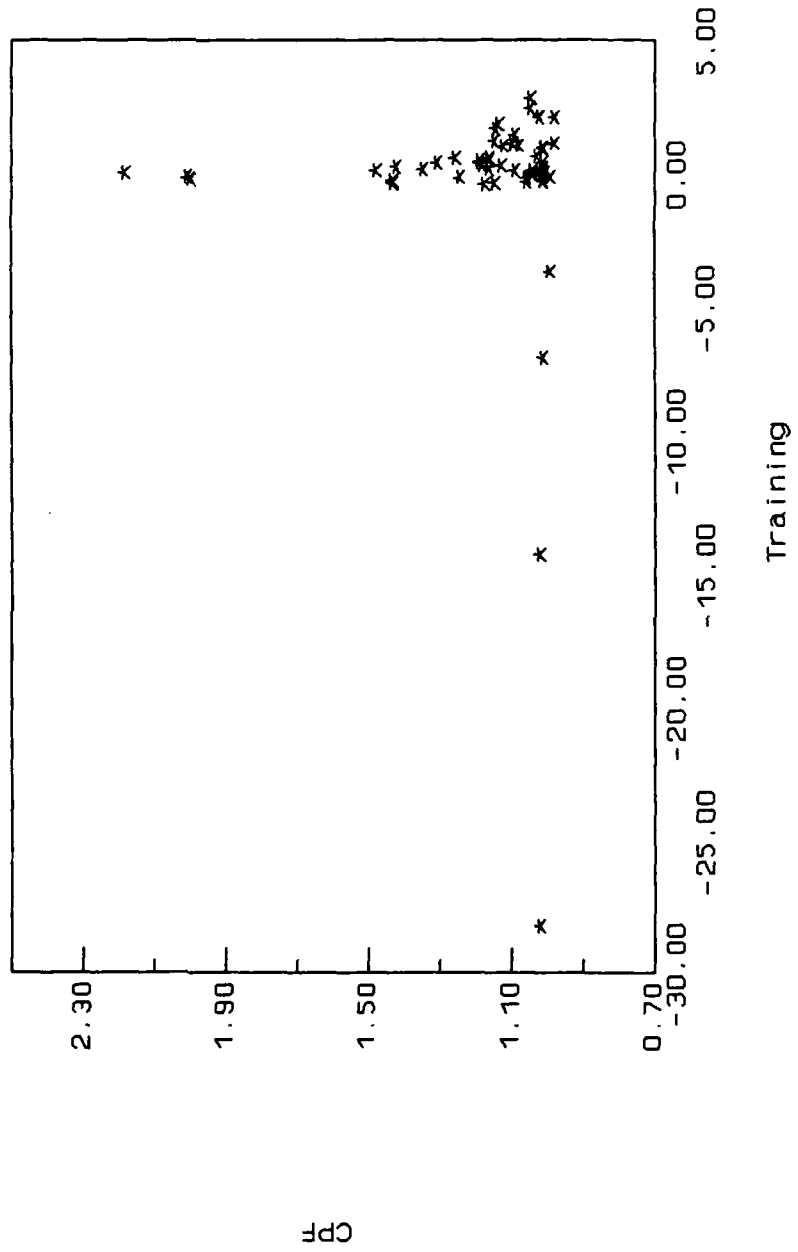
Figure 19: Scatter Plot -- TRAN
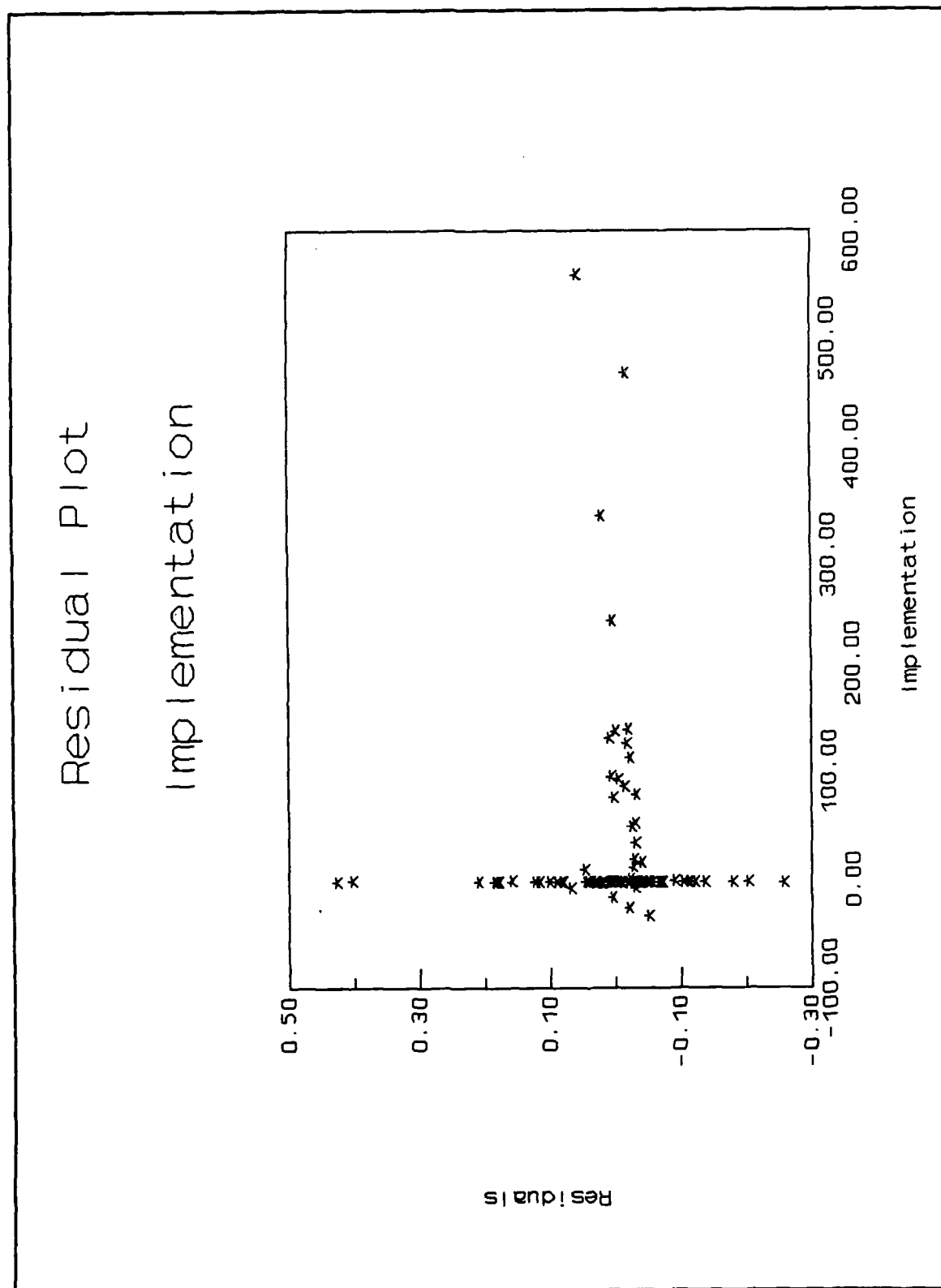
Figure 20: Residual Plot -- IMP
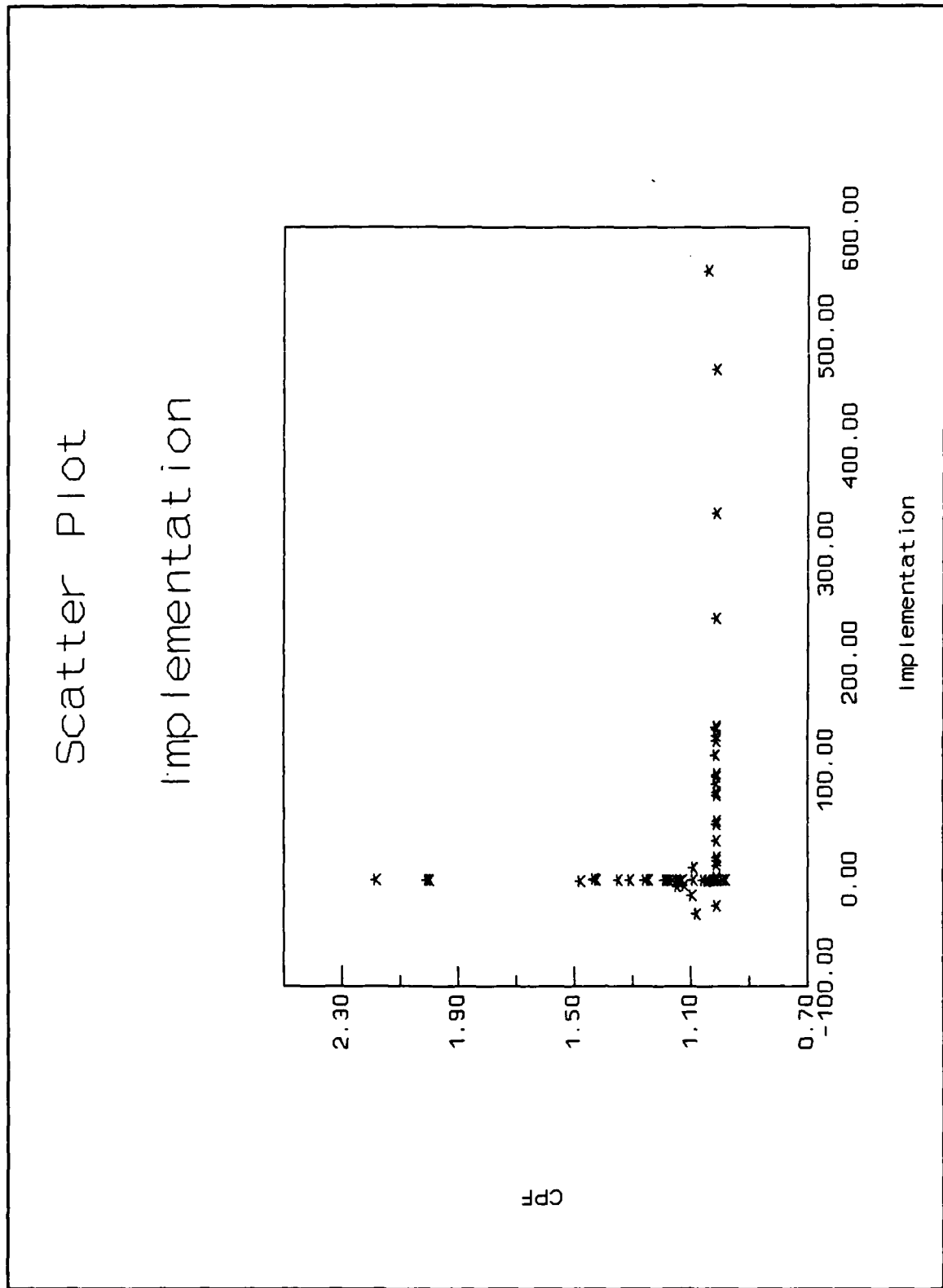
Figure 21: Scatter Plot -- IMP

53
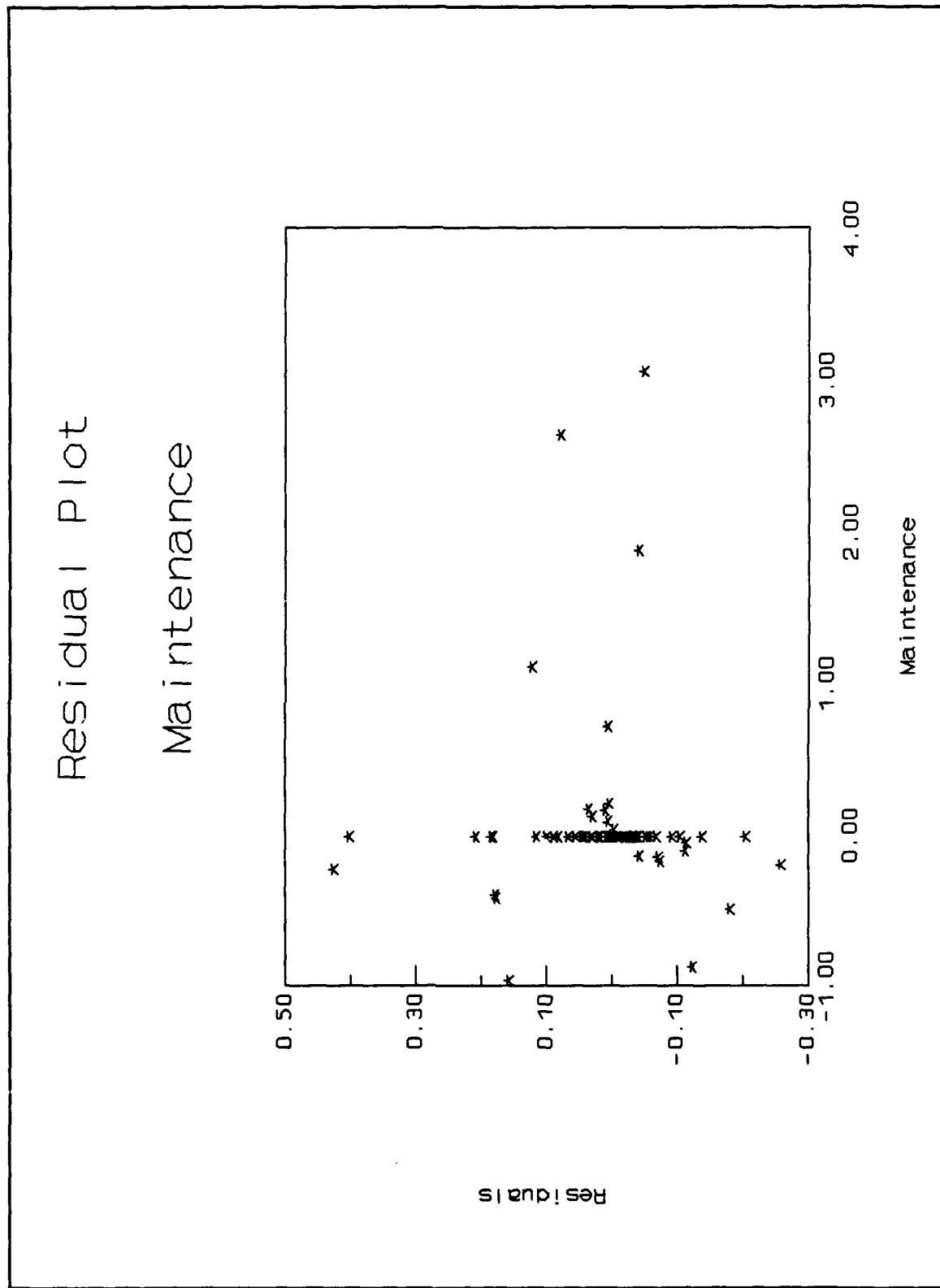
Figure 22: Residual Plot -- MAIN

Scatter Plot

Maintenance

Figure 23: Scatter Plot -- MAIN
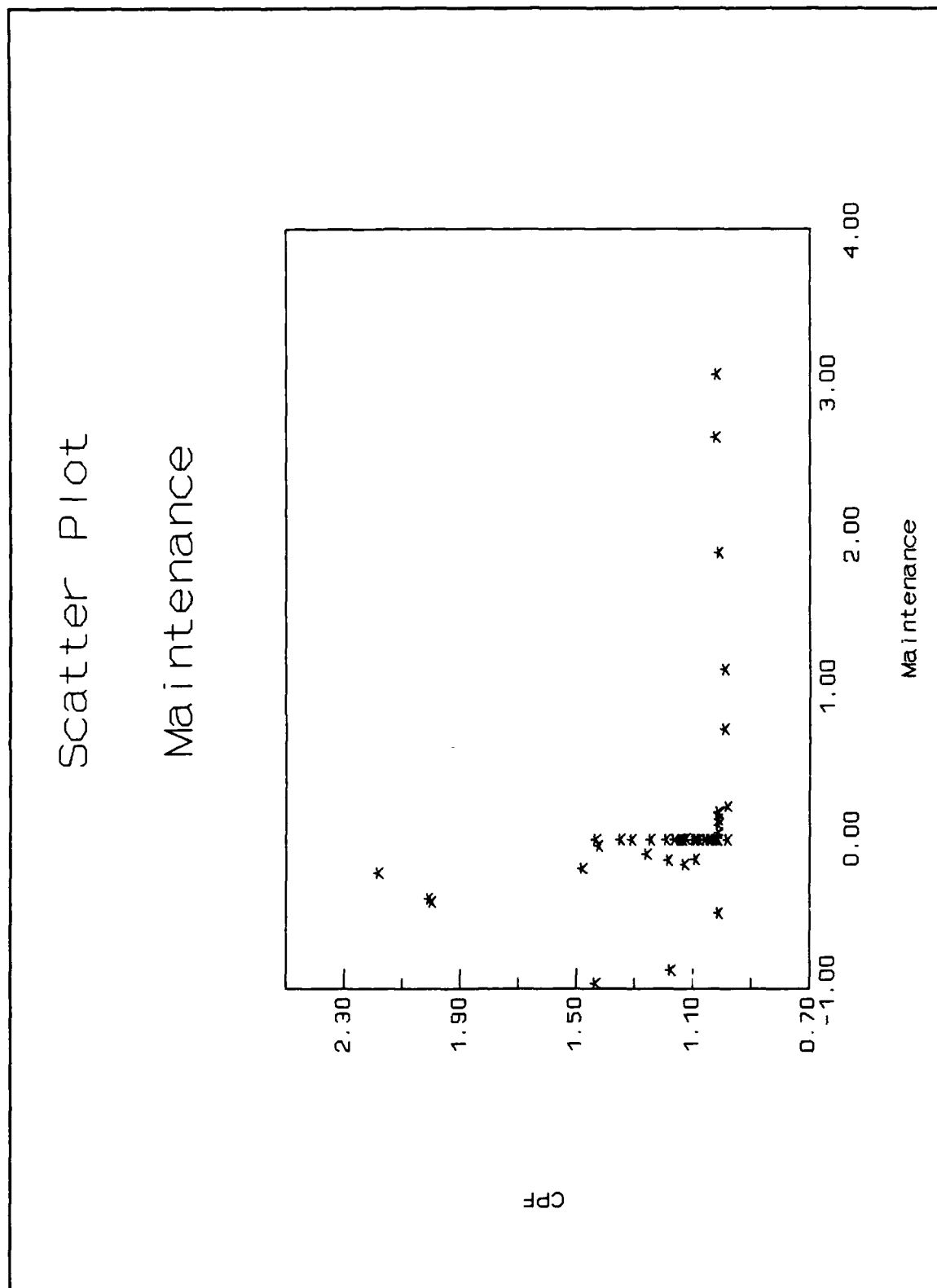
Appendix B: <u>Scatter</u> <u>Plots</u> <u>and</u> <u>Residual</u>
<u>Plots</u> <u>for</u> <u>Software</u> <u>Squared</u>
<u>in</u> <u>the</u> <u>Reduced</u> <u>Regression</u> <u>Model</u>

Scatter Plot

Software Squared
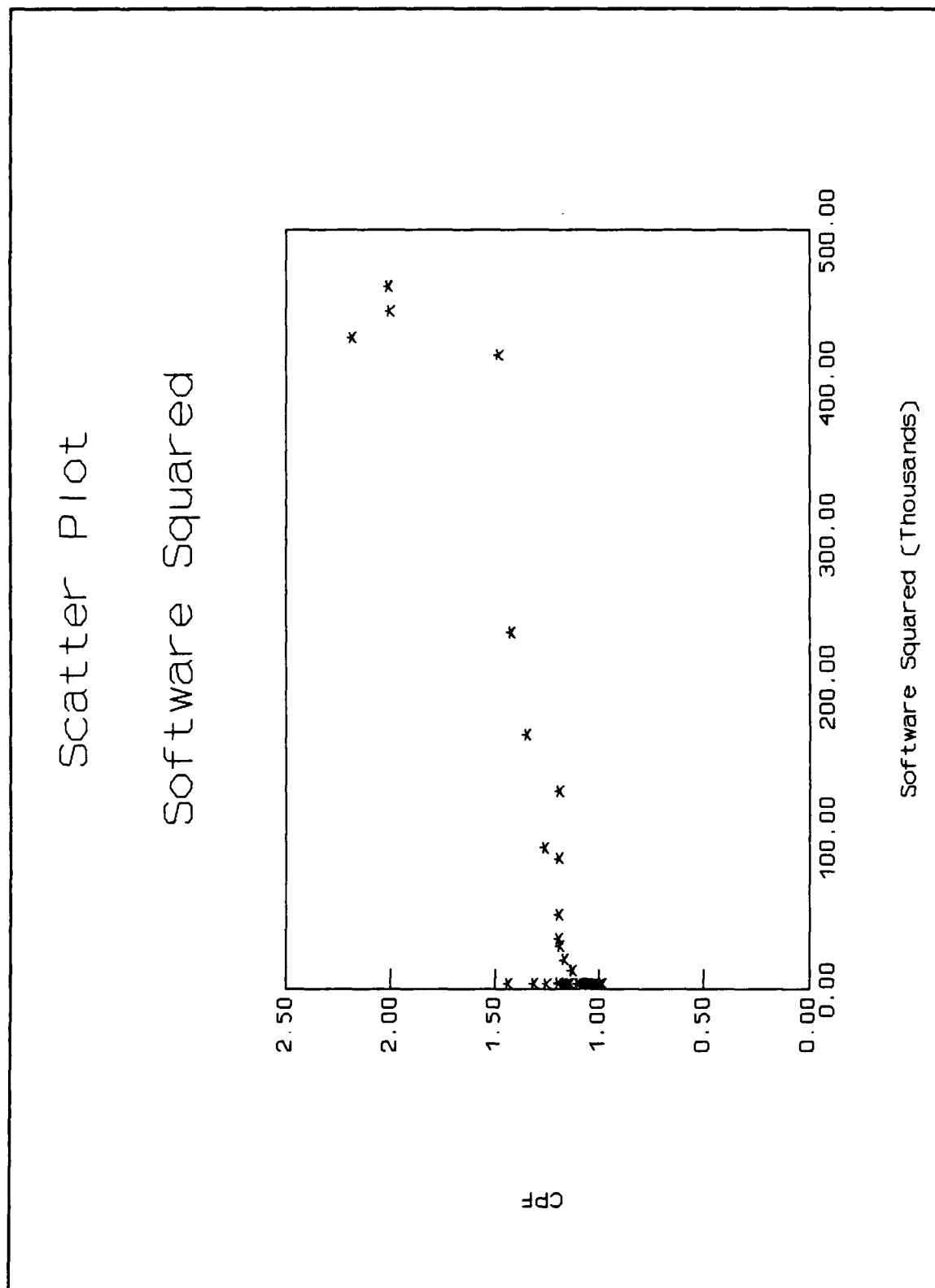
Figure 24: Scatter Plot -- SOFTS
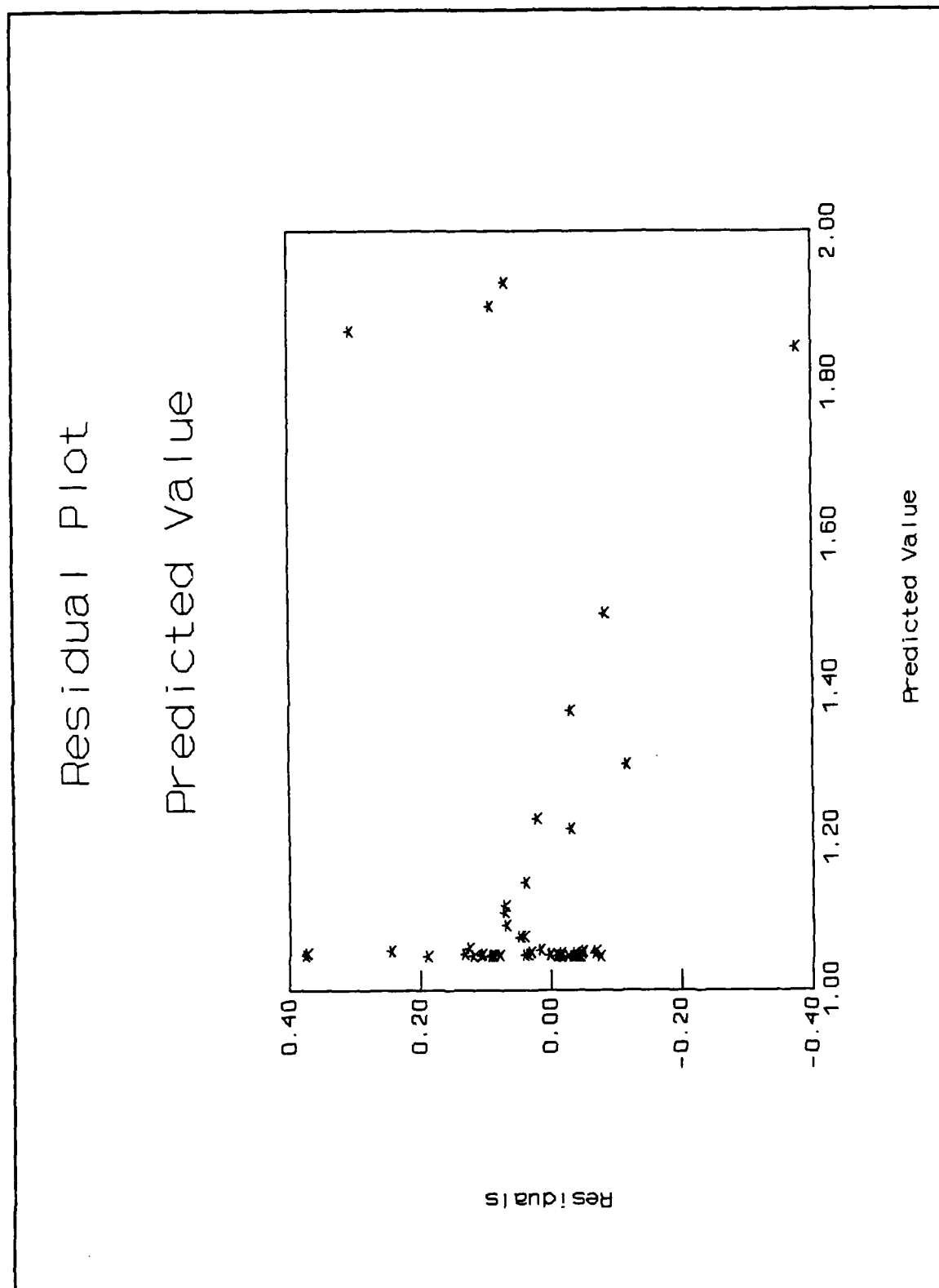
Residual Plot

Figure 25: Residual Plot -- Model
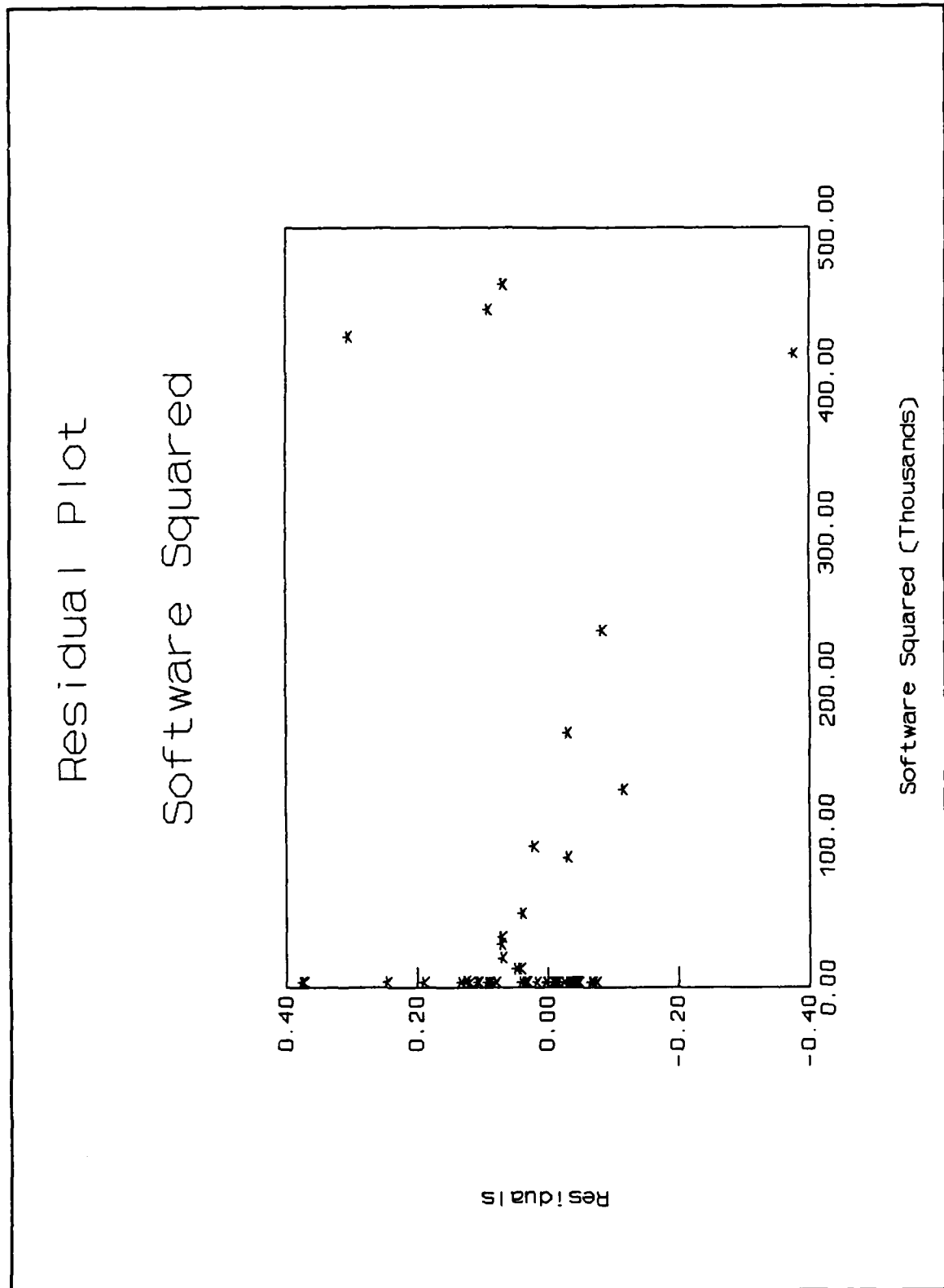
Figure 26: Residual Plot -- SOFTS

STEPWISE REGRESSION PROCEDURE FOR DEPENDENT VARIABLE RPPF

NOTE: SLENTRY AND SLSTAY HAVE BEEN SET TO
      .15 FOR THE STEPWISE TECHNIQUE.

STEP 1   VARIABLE SOFTS ENTERED   R SQUARE = 0.77174335
                                            C(P) =   15.24569223

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	1	2.98900240	2.98900240	284.01	0.0001
ERROR	84	0.88404997	0.01052440		
TOTAL	85	3.87305237			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	1.047707				
SOFTS	0.000001	0.00000011	2.98900240	284.01	0.0001

BOUNDS ON CONDITION NUMBER: 1,   1

****

STEP 2   VARIABLE MAIN ENTERED   R SQUARE = 0.78349191
                                            C(P) =   12.24037412

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	2	3.03450520	1.51725260	150.18	0.0001
ERROR	83	0.83854717	0.01010298		
TOTAL	85	3.87305237			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	1.05215250				
SOFTS	0.00000187	0.00000011	2.78329793	275.49	0.0001
MAIN	-0.04431821	0.02088276	0.04550280	4.50	0.0368

BOUNDS ON CONDITION NUMBER: 1.029143,   4.116573

****

```
STEP 3       VARIABLE COMM ENTERED            R SQUARE = 0.80089314
                                              C(P) =       6.82681392


             DF   SUM OF SQUARES  MEAN SQUARE    F     PROB>F

REGRESSION    3     3.10190107    1.03396702  109.95   0.0001
ERROR        82     0.77115130    0.00940428
TOTAL        85     3.87305237

             B VALUE     STD ERROR   TYPE II SS     F      PROB>F

INTERCEPT 1.04674522
SOFTS     0.00000181 0.00000011 2.47579974 263.26    0.0001
COMM      0.02272719 0.00848969 0.06739587   7.17    0.0090
MAIN     -0.17098612 0.05142747 0.10395782  11.05    0.0013

BOUNDS ON CONDITION NUMBER:        6.705236,      42.99346


*****************************************************************

STEP 4       VARIABLE TRAN ENTERED            R SQUARE = 0.80841691
                                              C(P) =       5.62141189

             DF   SUM OF SQUARES   MEAN SQUARE    F     PROB>F

REGRESSION    4     3.13104103     0.78276026   85.45   0.0001
ERROR        81     0.74201134     0.00916063
TOTAL        85     3.87305237

             B VALUE     STD ERROR   TYPE II SS     F      PROB>F

INTERCEPT 1.05091829
SOFTS     0.00000177 0.00000011 2.30931968 252.09    0.0001
COMM      0.01965036 0.00855474 0.04833399   5.28    0.0242
TRAN     -0.01044874 0.00585844 0.02913996   3.18    0.0782
MAIN     -0.21599482 0.05668422 0.13301108  14.52    0.0003

BOUNDS ON CONDITION NUMBER:        8.362736,      81.67514


*****************************************************************
```

STEP 5   VARIABLE TNE ENTERED   R SQUARE = 0.81930764
                                             C(P) =   2.98156225

                DF   SUM OF SQUARES   MEAN SQUARE   F   PROB>F

REGRESSION   5   3.17322139   0.63464428   72.55   0.0001
ERROR   80   0.69983098   0.00874789
TOTAL   85   3.87305237

                B VALUE   STD ERROR   TYPE II SS   F   PROB>F

INTERCEPT 1.04199568
SOFTS   0.00000180 0.00000011   2.34890195   268.51   0.0001
COMM   0.01822989 0.00838479   0.04135111   4.73   0.0326
TNE   -0.00020135 0.00009169   0.04218037   4.82   0.0310
TRAN   -0.01310525 0.00585137   0.04388119   5.02   0.0279
MAIN   -0.22041581 0.05542908   0.13832902   15.81   0.0002

BOUNDS ON CONDITION NUMBER: 8.373784,   108.6699

NO OTHER VARIABLES MET THE 0.1500 SIGNIFICANCE LEVEL FOR
ENTRY

****

                        SUMMARY OF
STEPWISE REGRESSION PROCEDURE FOR DEPENDENT VARIABLE CPF

             VARIABLE NUMBER PARTIAL   MODEL
STEP ENTERED REMOVED   IN   R**2   R**2   C(P)

  1   SOFTS   1   0.7717   0.7717 15.2457
  2   MAIN   2   0.0117   0.7835 12.2404
  3   COMM   3   0.0174   0.8009   6.8268
  4   TRAN   4   0.0075   0.8084   5.6214
  5   TNE   5   0.0109   0.8193   2.9816

              VARIABLE
STEP   ENTERED   REMOVED   F   PROB>F

  1   SOFTS   284.0068   0.0001
  2   MAIN   4.5039   0.0368
  3   COMM   7.1665   0.0090
  4   TRAN   3.1810   0.0782
  5   TNE   4.8218   0.0310

Appendix D: Results From
SAS RSQUARE Procedure

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N=86 REGRESSION MODELS FOR DEPENDENT VARIABLE: CPF

IN	RSQ	ADJ RSQ	SSE	MSE	C(P)	VARIABLES IN MODEL
1	0.0001	-.0118	3.873	0.0461	344	TNE
1	0.0013	-.0106	3.868	0.0460	343.49	HARD
1	0.0046	-.0073	3.855	0.0459	342.09	TRAN
1	0.0119	0.0001	3.827	0.0456	338.99	COMM
1	0.0119	0.0002	3.827	0.0456	338.95	MGMT
1	0.0224	0.0108	3.786	0.0451	334.47	FAC
1	0.0226	0.0109	3.786	0.0451	334.42	DATA
1	0.0295	0.0179	3.759	0.0447	331.48	IMP
1	0.0337	0.0222	3.742	0.0446	329.67	SYEN
1	0.0649	0.0537	3.622	0.0431	316.4	MAIN
1	0.7717	0.7690	0.884	0.0105	15.246	SOFTS
2	0.1617	0.1415	3.247	0.0391	277.17	COMM MAIN
2	0.7718	0.7663	0.884	0.0107	17.236	HARD SOFTS
2	0.7731	0.7677	0.879	0.0106	16.646	SOFTS TRAN
2	0.7741	0.7686	0.875	0.0105	16.262	SOFTS COMM
2	0.7753	0.7698	0.870	0.0105	15.747	SYEN SOFTS
2	0.7760	0.7706	0.868	0.0105	15.45	SOFTS FAC
2	0.7769	0.7715	0.864	0.0104	15.046	SOFTS IMP
2	0.7771	0.7717	0.863	0.0104	14.959	SOFTS DATA
2	0.7798	0.7745	0.853	0.0103	13.816	MGMT SOFTS
2	0.7812	0.7759	0.848	0.0102	13.237	SOFTS TNE
2	0.7835	0.7783	0.839	0.0101	12.24	SOFTS MAIN
3	0.7840	0.7761	0.837	0.0102	14.024	SOFTS FAC TNE
3	0.7840	0.7761	0.837	0.0102	14.019	MGMT SOFTS DATA
3	0.7844	0.7765	0.835	0.0102	13.873	SOFTS TNE IMP
3	0.7849	0.7770	0.833	0.0102	13.647	HARD SOFTS MAIN
3	0.7867	0.7789	0.826	0.0101	12.885	SOFTS DATA MAIN
3	0.7886	0.7809	0.819	0.0100	12.067	SOFTS FAC MAIN
3	0.7898	0.7821	0.814	0.0099	11.551	SOFTS IMP MAIN
3	0.7898	0.7821	0.814	0.0099	11.549	MGMT SOFTS MAIN
3	0.7914	0.7837	0.808	0.0099	10.889	SOFTS TNE MAIN
3	0.7959	0.7885	0.790	0.0096	8.9382	SOFTS TRAN MAIN
3	0.8009	0.7936	0.771	0.0094	6.8268	SOFTS COMM MAIN

IN	RSQ	ADJ RSQ	SSE	MSE	C(P)	VARIABLES IN MODEL
4	0.8016	0.7918	0.769	0.0095	8.5411	HARD SOFTS COMM MAIN
4	0.8020	0.7922	0.767	0.0095	8.3615	SOFTS FAC TRAN MAIN
4	0.8025	0.7927	0.765	0.0094	8.1561	MGMT SOFTS TRAN MAIN
4	0.8036	0.7939	0.761	0.0094	7.6851	SOFTS TRAN IMP MAIN
4	0.8039	0.7942	0.760	0.0094	7.5665	SOFTS COMM DATA MAIN
4	0.8050	0.7953	0.755	0.0093	7.0947	SOFTS COMM FAC MAIN
4	0.8058	0.7962	0.752	0.0093	6.7255	SOFTS COMM IMP MAIN
4	0.8080	0.7985	0.744	0.0092	5.8085	SOFTS COMM TNE MAIN
4	0.8083	0.7988	0.743	0.0092	5.682	MGMT SOFTS COMM MAIN
4	0.8084	0.7990	0.742	0.0092	5.6214	SOFTS COMM TRAN MAIN
4	0.8086	0.7992	0.741	0.0092	5.5302	SOFTS TNE TRAN MAIN
5	0.8108	0.7990	0.733	0.0092	6.5882	SOFTS COMM FAC TNE MAIN
5	0.8112	0.7994	0.731	0.0091	6.4362	SOFTS COMM TNE IMP MAIN
5	0.8112	0.7994	0.731	0.0091	6.4282	MGMT SOFTS COMM FAC MAIN
5	0.8115	0.7997	0.730	0.0091	6.3191	HARD SOFTS TNE TRAN MAIN
5	0.8119	0.8001	0.729	0.0091	6.1416	MGMT SOFTS COMM IMP MAIN
5	0.8128	0.8011	0.725	0.0091	5.747	SOFTS FAC TNE TRAN MAIN
5	0.8133	0.8016	0.723	0.0090	5.5376	SOFTS COMM FAC TRAN MAIN
5	0.8135	0.8019	0.722	0.0090	5.4381	SOFTS TNE TRAN IMP MAIN
5	0.8145	0.8029	0.718	0.0090	5.0336	SOFTS COMM TRAN IMP MAIN
5	0.8158	0.8043	0.713	0.0089	4.4623	MGMT SOFTS COMM TRAN MAIN
5	0.8193	0.8080	0.700	0.0087	2.9816	SOFTS COMM TNE TRAN MAIN

IN	RSQ	ADJ RSQ	SSE	MSE	C(P)	VARIABLES IN MODEL
6	0.8162	0.8023	0.712	0.0090	6.3	SOFTS COMM DATA TRAN IMP MAIN
6	0.8167	0.8028	0.710	0.0090	6.0829	MGMT SOFTS COMM DATA TRAN MAIN
6	0.8174	0.8035	0.707	0.0090	5.8146	MGMT HARD SOFTS COMM TRAN MAIN
6	0.8193	0.8056	0.700	0.0089	4.9681	SOFTS COMM TNE DATA TRAN MAIN
6	0.8195	0.8058	0.699	0.0088	4.9064	MGMT SOFTS COMM FAC TRAN MAIN
6	0.8197	0.8060	0.698	0.0088	4.8031	SYEN SOFTS COMM TNE TRAN MAIN
6	0.8203	0.8067	0.696	0.0088	4.5508	MGMT SOFTS COMM TNE TRAN MAIN
6	0.8204	0.8068	0.695	0.0088	4.5009	MGMT SOFTS COMM TRAN IMP MAIN
6	0.8210	0.8074	0.693	0.0088	4.2658	HARD SOFTS COMM TNE TRAN MAIN
6	0.8227	0.8092	0.687	0.0087	3.5338	SOFTS COMM FAC TNE TRAN MAIN
6	0.8232	0.8098	0.685	0.0087	3.3222	SOFTS COMM TNE TRAN IMP MAIN
7	0.8216	0.8056	0.691	0.0089	5.9933	MGMT SOFTS COMM DATA TRAN IMP MAIN
7	0.8219	0.8059	0.690	0.0088	5.8767	MGMT HARD SOFTS COMM TNE TRAN MAIN
7	0.8228	0.8069	0.686	0.0088	5.4819	SOFTS COMM FAC TNE DATA TRAN MAIN
7	0.8229	0.8070	0.686	0.0088	5.4713	SYEN SOFTS COMM FAC TNE TRAN MAIN
7	0.8232	0.8073	0.685	0.0088	5.3213	SYEN SOFTS COMM TNE TRAN IMP MAIN
7	0.8233	0.8074	0.684	0.0088	5.278	HARD SOFTS COMM FAC TNE TRAN MAIN
7	0.8234	0.8075	0.684	0.0088	5.2548	SOFTS COMM TNE DATA TRAN IMP MAIN
7	0.8235	0.8077	0.684	0.0088	5.1913	MGMT SOFTS COMM FAC TNE TRAN MAIN
7	0.8237	0.8078	0.683	0.0088	5.1299	HARD SOFTS COMM TNE TRAN IMP MAIN
7	0.8241	0.8083	0.681	0.0087	4.9576	MGMT SOFTS COMM TNE TRAN IMP MAIN
7	0.8242	0.8085	0.681	0.0087	4.8822	SOFTS COMM FAC TNE TRAN IMP MAIN

IN	RSQ	ADJ RSQ	SSE	MSE	C(P)	VARIABLES IN MODEL
8	0.8237	0.8054	0.683	0.0089	7.1044	MGMT SOFTS COMM FAC TNE DATA TRAN MAIN
8	0.8238	0.8055	0.682	0.0089	7.0536	MGMT SYEN SOFTS COMM FAC TNE TRAN MAIN
8	0.8240	0.8057	0.682	0.0089	6.9771	HARD SOFTS COMM TNE DATA TRAN IMP MAIN
8	0.8241	0.8058	0.681	0.0088	6.9498	MGMT SYEN SOFTS COMM TNE TRAN IMP MAIN
8	0.8241	0.8058	0.681	0.0088	6.9481	MGMT HARD SOFTS COMM FAC TNE TRAN MAIN
8	0.8243	0.8061	0.680	0.0088	6.849	MGMT SOFTS COMM TNE DATA TRAN IMP MAIN
8	0.8244	0.8062	0.680	0.0088	6.7982	SOFTS COMM FAC TNE DATA TRAN IMP MAIN
8	0.8245	0.8062	0.680	0.0088	6.7888	SYEN SOFTS COMM FAC TNE TRAN IMP MAIN
8	0.8245	0.8062	0.680	0.0088	6.779	MGMT HARD SOFTS COMM TNE TRAN IMP MAIN
8	0.8245	0.8063	0.680	0.0088	6.7728	HARD SOFTS COMM FAC TNE TRAN IMP MAIN
8	0.8250	0.8068	0.678	0.0088	6.5525	MGMT SOFTS COMM FAC TNE TRAN IMP MAIN
9	0.8243	0.8035	0.680	0.0090	8.8398	MGMT SYEN SOFTS COMM TNE DATA TRAN IMP MAIN
9	0.8245	0.8037	0.680	0.0089	8.7661	MGMT SYEN HARD SOFTS COMM FAC TNE TRAN MAIN
9	0.8245	0.8038	0.680	0.0089	8.7541	MGMT SYEN HARD SOFTS COMM TNE TRAN IMP MAIN
9	0.8245	0.8038	0.680	0.0089	8.7495	MGMT HARD SOFTS COMM FAC TNE DATA TRAN MAIN
9	0.8247	0.8039	0.679	0.0089	8.7005	SYEN SOFTS COMM FAC TNE DATA TRAN IMP MAIN

IN	RSQ	ADJ RSQ	SSE	MSE	C(P)	VARIABLES IN MODEL
9	0.8248	0.8040	0.679	0.0089	8.6577	SYEN HARD SOFTS COMM FAC TNE TRAN IMP MAIN
9	0.8249	0.8041	0.678	0.0089	8.6203	HARD SOFTS COMM FAC TNE DATA TRAN IMP MAIN
9	0.8250	0.8042	0.678	0.0089	8.5691	MGMT HARD SOFTS COMM TNE DATA TRAN IMP MAIN
9	0.8252	0.8046	0.677	0.0089	8.4503	MGMT HARD SOFTS COMM FAC TNE TRAN IMP MAIN
9	0.8253	0.8046	0.677	0.0089	8.4264	MGMT SOFTS COMM FAC TNE DATA TRAN IMP MAIN
9	0.8254	0.8048	0.676	0.0089	8.3719	MGMT SYEN SOFTS COMM FAC TNE TRAN IMP MAIN
10	0.2904	0.1957	2.748	0.0366	238.33	MGMT SYEN HARD COMM FAC TNE DATA TRAN IMP MAIN
10	0.7925	0.7648	0.804	0.0107	24.41	MGMT SYEN HARD SOFTS COMM FAC TNE DATA TRAN IMP
10	0.8181	0.7939	0.704	0.0094	13.488	MGMT SYEN HARD SOFTS FAC TNE DATA TRAN IMP MAIN
10	0.8186	0.7945	0.702	0.0094	13.266	MGMT SYEN HARD SOFTS COMM FAC TNE DATA IMP MAIN
10	0.8241	0.8006	0.681	0.0091	10.952	MGMT SYEN HARD SOFTS COMM FAC DATA TRAN IMP MAIN
10	0.8250	0.8017	0.678	0.0090	10.537	MGMT SYEN HARD SOFTS COMM FAC TNE DATA TRAN MAIN
10	0.8251	0.8017	0.678	0.0090	10.533	MGMT SYEN HARD SOFTS COMM TNE DATA TRAN IMP MAIN
10	0.8252	0.8018	0.677	0.0090	10.491	SYEN HARD SOFTS COMM FAC TNE DATA TRAN IMP MAIN
10	0.8257	0.8025	0.675	0.0090	10.243	MGMT HARD SOFTS COMM FAC TNE DATA TRAN IMP MAIN
10	0.8257	0.8025	0.675	0.0090	10.241	MGMT SYEN HARD SOFTS COMM FAC TNE TRAN IMP MAIN

IN	RSQ	ADJ RSQ	SSE	MSE	C(P)	VARIABLES IN MODEL
10	0.8258	0.8025	0.675	0.0090	10.231	MGMT SYEN SOFTS COMM FAC TNE DATA TRAN IMP MAIN
11	0.8263	0.8005	0.673	0.0091	12	MGMT SYEN HARD SOFTS COMM FAC TNE DATA TRAN IMP MAIN

IN	RSQ	ADJ RSQ	SSE	MSE	C(P)	VARIABLES IN MODEL

Appendix E: Regression Results
For Five Variable Model

DEP VARIABLE: CPF

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	5	3.14808147	0.62961629	69.478	0.0001
ERROR	80	0.72497089	0.00906213		
C TOTAL	85	3.87305237			

ROOT MSE	0.09519525	R-SQUARE	0.8128
DEP MEAN	1.107393	ADJ R-SQ	0.8011
C.V.	8.596336		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB>|T|
INTERCEP	1	1.05210457	0.01265263	83.153	0.0001
SOFTS	1	.00000182213	1.1077E-07	16.449	0.0001
FAC	1	0.0112034	0.00837640	1.337	0.1849
TNE	1	-0.000201663	.000093728	-2.152	0.0344
TRAN	1	-0.0160566	0.00582221	-2.758	0.0072
MAIN	1	-0.137938	0.03970543	-3.474	0.0008

Appendix F: Regression Results For Model with Four Variables

DEP VARIABLE: CPF

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	4	3.13187028	0.78296757	85.567	0.0001
ERROR	81	0.74118208	0.00915039		
C TOTAL	85	3.87305237			

ROOT MSE	0.0956577	R-SQUARE	0.8086
DEP MEAN	1.107393	ADJ R-SQ	0.7992
C.V.	8.638096		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB>|T|
INTERCEP	1	1.04644972	0.01198326	87.326	0.0001
SOFTS	1	0.00000184	1.10427E-07	16.670	0.0001
TNE	1	-0.00021672	.00009350127	-2.318	0.0230
TRAN	1	-0.0158107	0.005847582	-2.704	0.0084
MAIN	1	-0.134643	0.03982144	-3.381	0.0011

Appendix G: <u>Regression</u> <u>Analysis</u> <u>With</u> <u>Partial</u> <u>F-Test</u>

DEP VARIABLE: CPF

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	5	3.14808147	0.62961629	69.478	0.0001
ERROR	80	0.72497089	0.009062136		
C TOTAL	85	3.87305237			

ROOT MSE	0.09519525	R-SQUARE	0.8128
DEP MEAN	1.107393	ADJ R-SQ	0.8011
C.V.	8.596336		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB>|T|
INTERCEP	1	1.05210457	0.01265263	83.153	0.0001
SOFTS	1	.000001822	1.10777E-07	16.449	0.0001
FAC	1	0.0112034	0.008376402	1.337	0.1849
TNE	1	-0.0002016	.000093728	-2.152	0.0344
TRAN	1	-0.0160566	0.00582221	-2.758	0.0072
MAIN	1	-0.137938	0.03970543	-3.474	0.0008

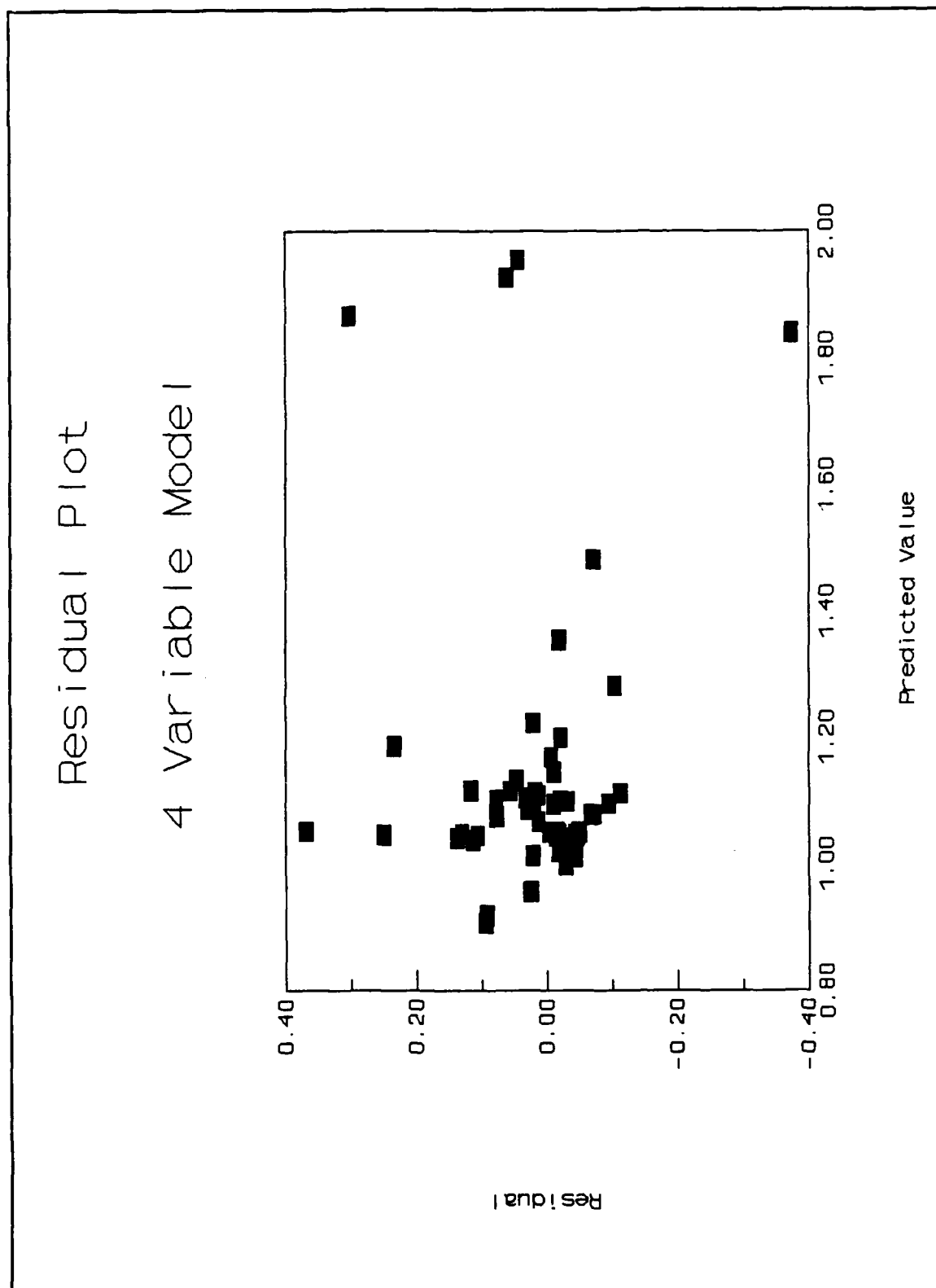| TEST: F1	NUMERATOR:	.0162112	DF:	1	F VALUE:	1.788
	DENOMINATOR:	.0090621	DF:	80	PROB>F:	0.1849

Appendix H: Residual Plots
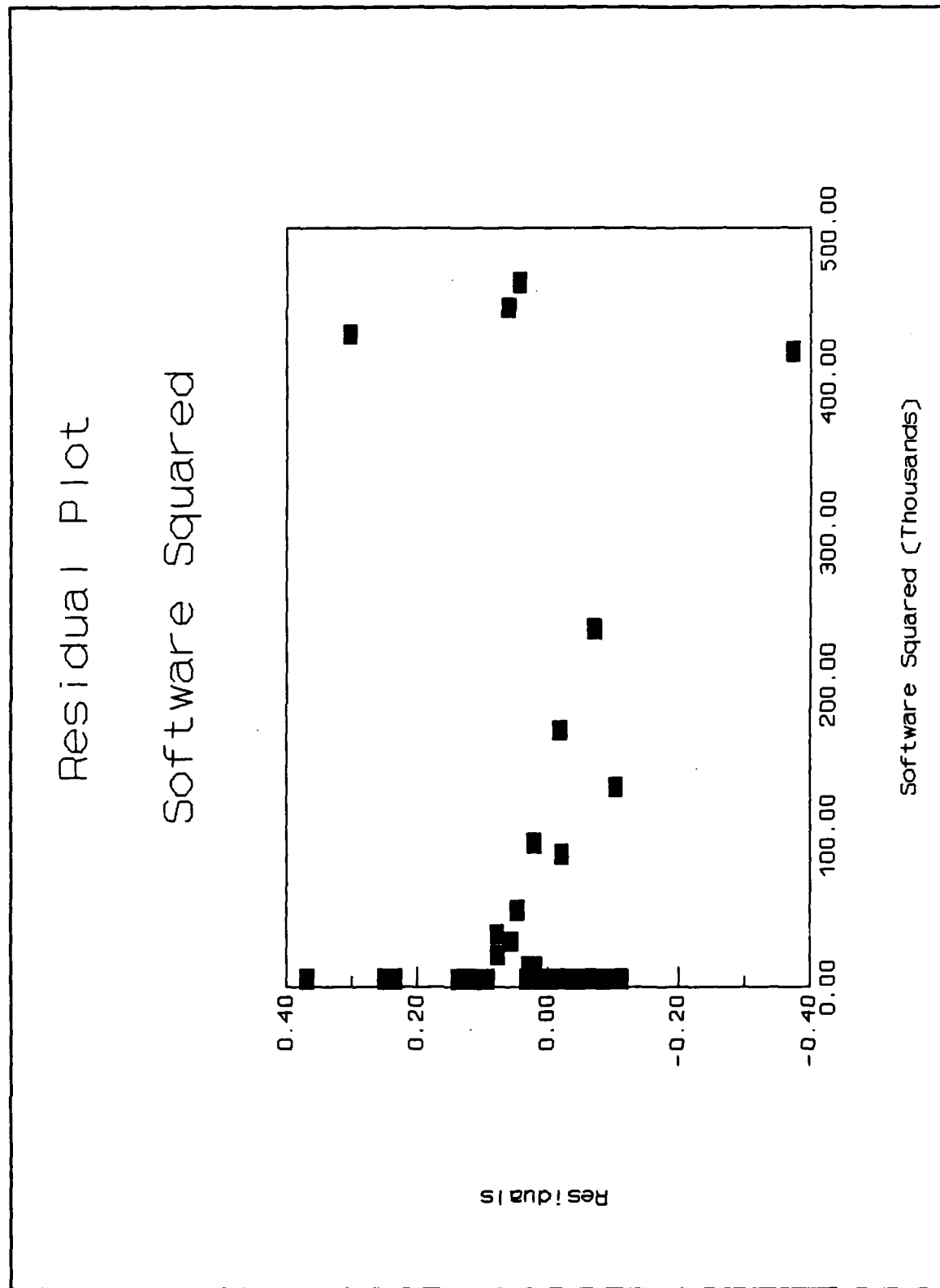4 Variable Model

Figure 27: Residual Plot -- Model
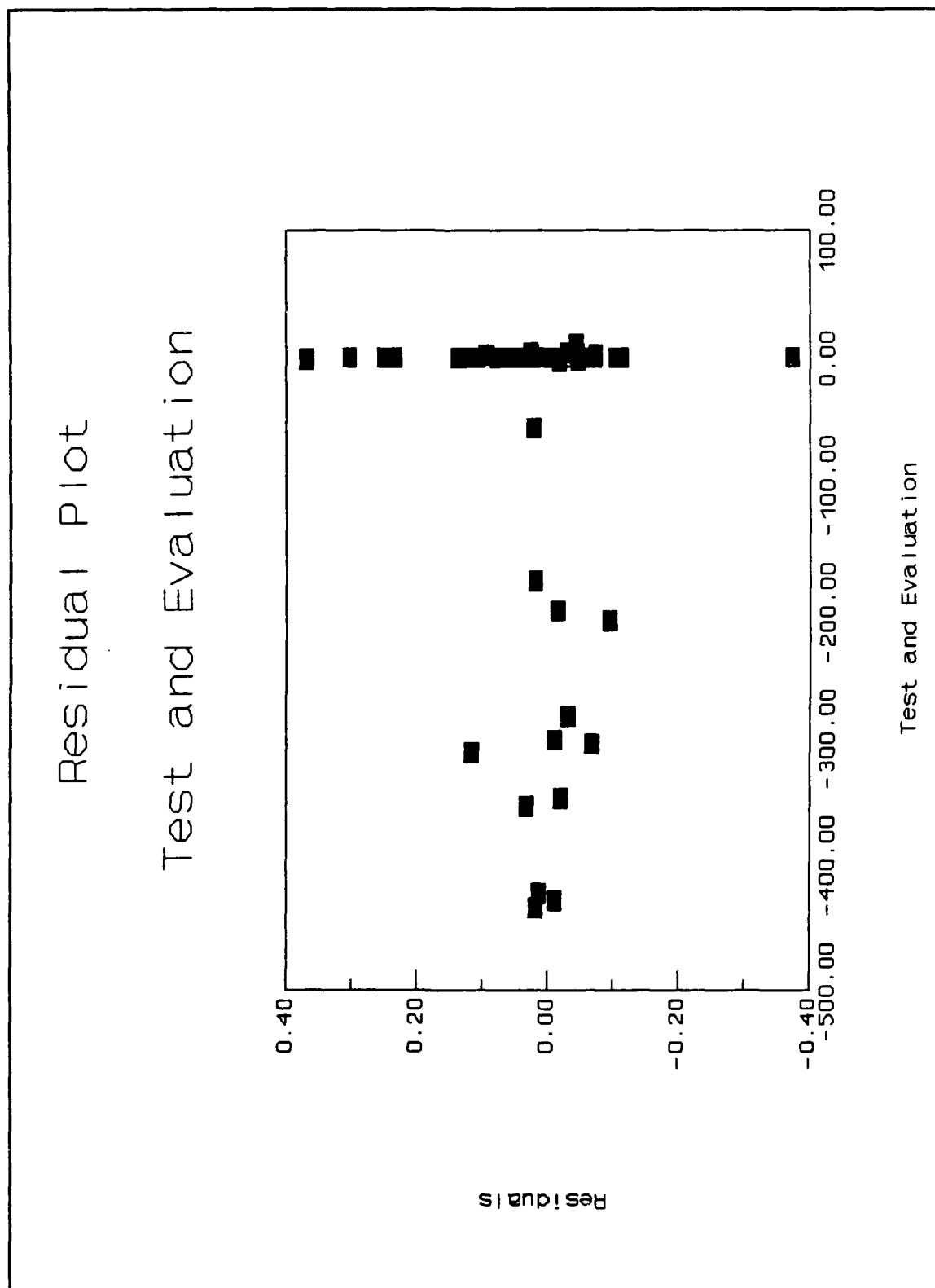
Figure 28: Residual Plot -- SOFTS

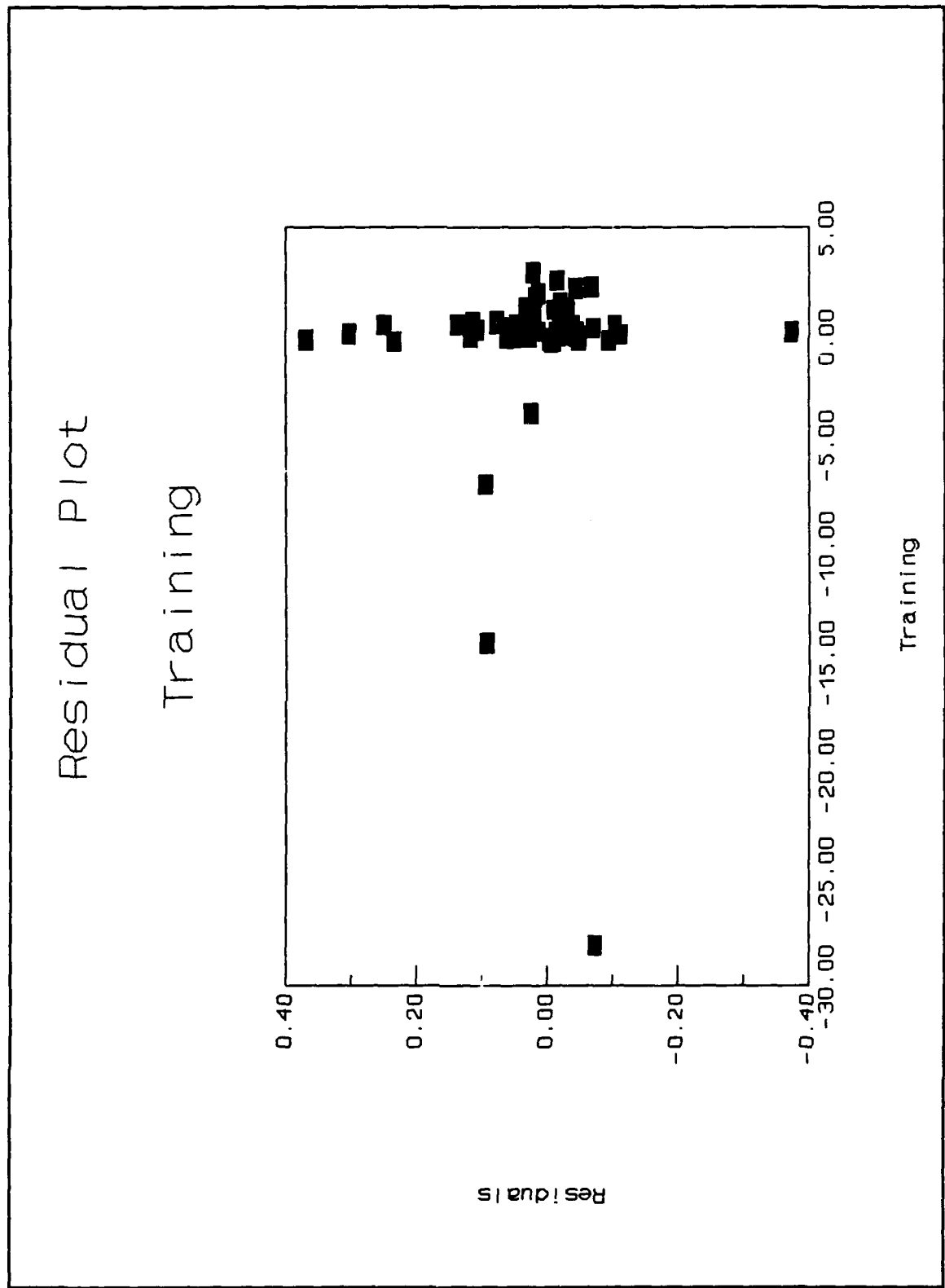**Figure 29: Residual Plot -- TNE**

75

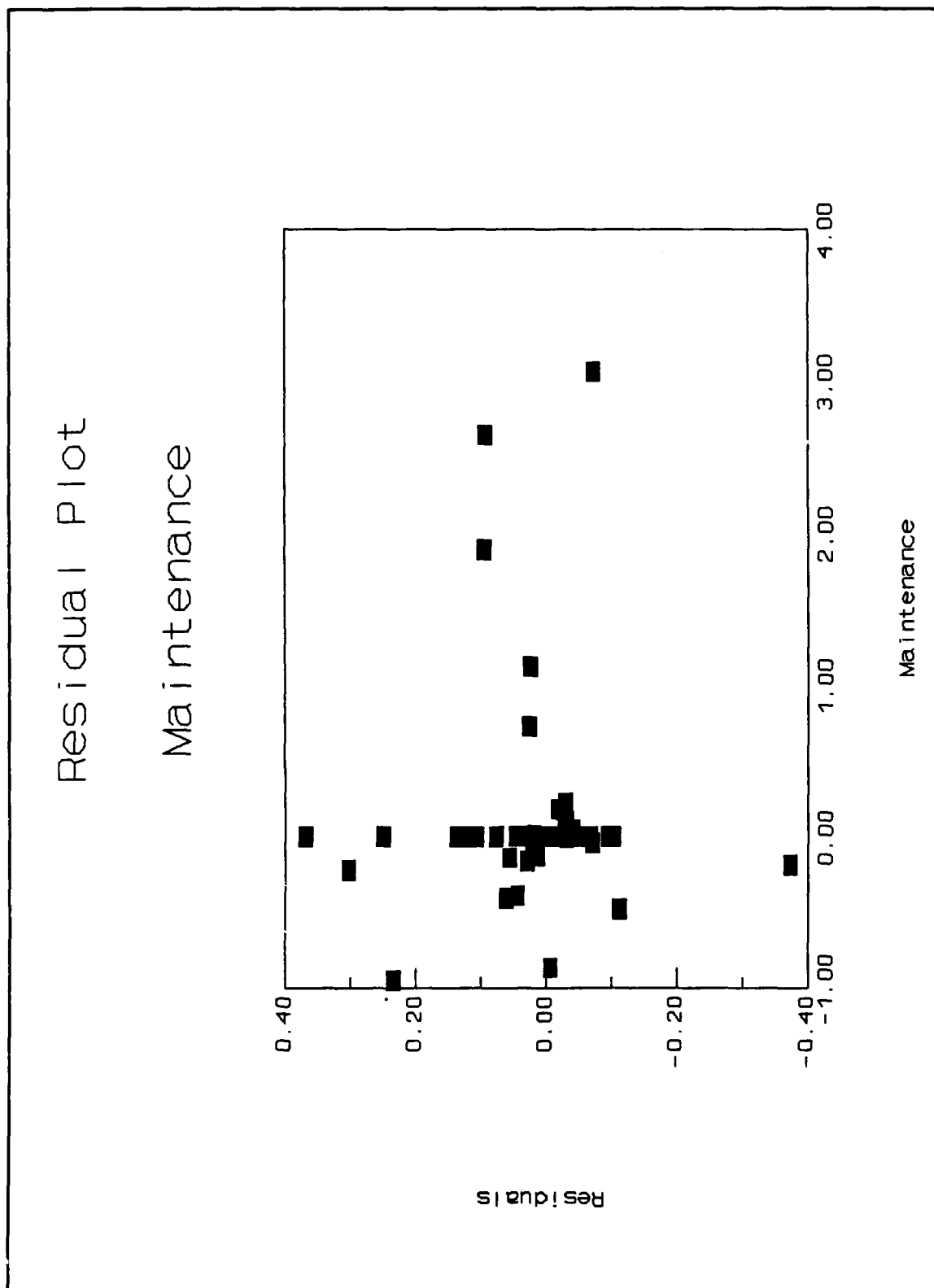**Figure 30: Residual Plot -- TRAN**

Figure 31: Residual Plot -- MAIN

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Vita

Captain Thomas J. Falkowski was born on ███████████████ ████████████████████████ He graduated ████████████ High School ████████████████████████████ 1975. He then attended the School of Management at Boston College in Chestnut Hill, Massachusetts. He received a Bachelor of Science degree in Finance from Boston College in May of 1979. He enlisted in the USAF in December of 1982. After completion of training, he served as a weather specialist at Detachment 11, 7th Weather Squadron, Coleman Barracks, West Germany. In July 1984, he enter OTS at Lackland AFB TX and received his commission in October 1984. After completion of Administrative Officers' School at Keesler AFB MS, he was assigned to the 9th Strategic Reconnaissance Wing, Beale AFB California. While at Beale AFB, he served as the Executive Officer, and then, as the Squadron Section Commander for the 9th Civil Engineering Squadron. He attended Squadron Officer School at Maxwell AFB AL prior to entering the School of Systems and Logistics, Air Force Institute of Technology, in June 1987.
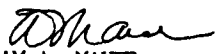
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The purpose of this study was to identify indicators that
can be used to more efficiently control the acquisition costs
of Air Force information systems. Statistical analysis was
performed on cost data collected from Cost/Schedule Status Reports
from information systems acquired under Air Force Logistics
Command's Logistics Management Systems Modernization Program.
Using regression analysis, an initial model was developed that
showed the significance of various cost areas on contract
performance. The model was then transformed and reduced, to
include only those variables that added significantly to the
prediction of contract performance.

Based on the sample analyzed the following cost areas were
identified as key indicators of contract performance: Software,
Test and Evaluation, Training, and Maintenance. Although the
limited size of the sample data make the results inconclusive,
the methodology presented here provides a means to identify
potential indicators. The goal of this research was not to
provide a definitive model that would help program managers to
predict contractor performance. Instead, the goal was to establish
procedures or motivation, for program managers to identify key
control variables that can help them to manage their programs more
efficiently in a time of austere budgets and restricted man-
power availabilty.